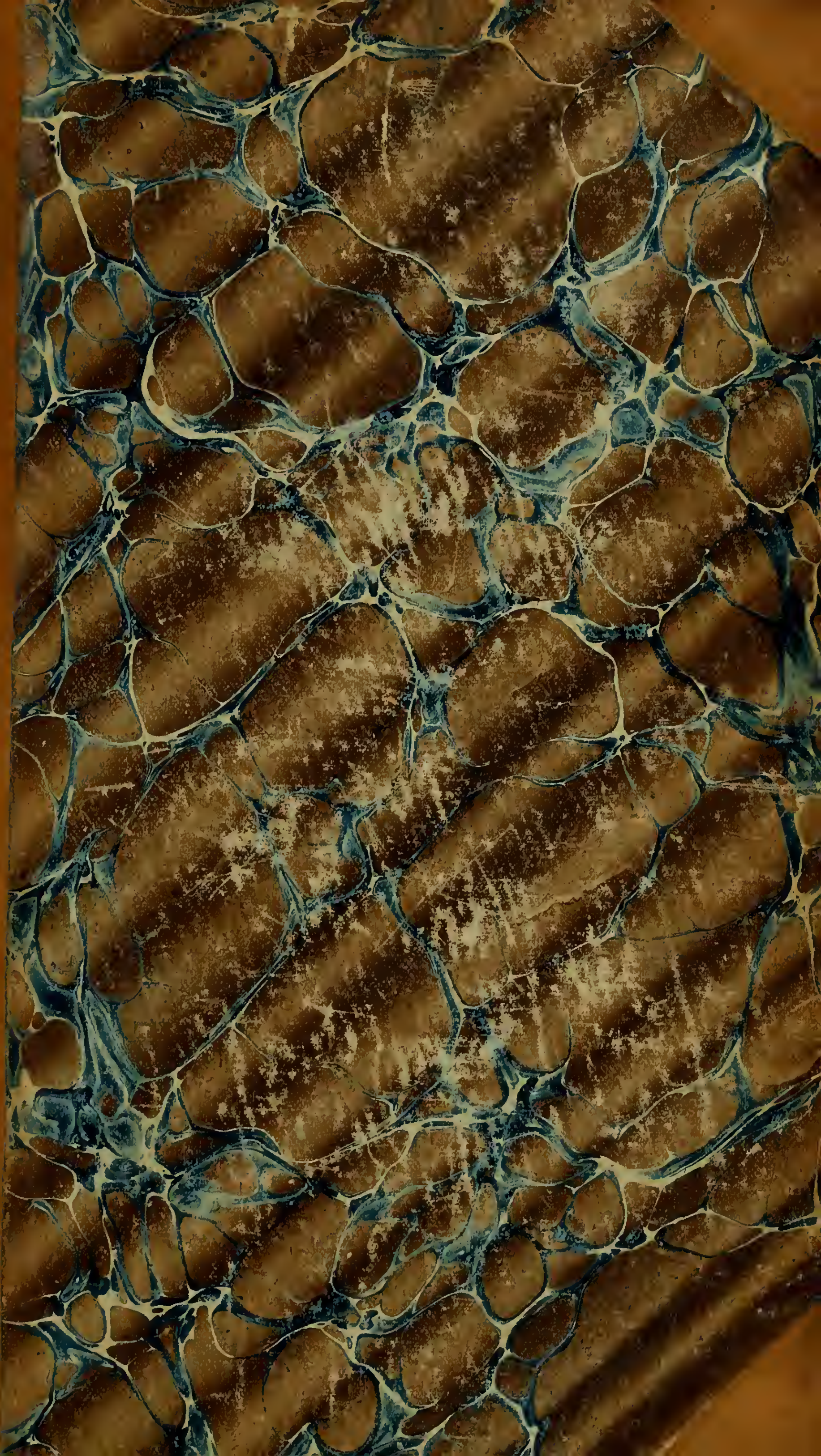


Digitized by the Internet Archive
in 2010 with funding from
University of Toronto

http://www.archive.org/details/journalfranklini141fran

Tech
F

THE JOURNAL

—OF THE—

FRANKLIN INSTITUTE,

111

DEVOTED TO

SCIENCE AND THE MECHANIC ARTS.

EDITED BY

Prof. Edwin J. Houston, A.M., Ph.D., Chairman; Prof. Arthur Beardsley,
C.E., Ph.D., Mr. Theo. D. Rand, Prof. Coleman Sellers, E.D.,
Prof. S. P. Sadtler, Committee on Publications,
with the Assistance of Dr. Wm. H. Wahl,
Secretary of the Institute.

VOL. CXLI.—Nos. 841-846.

JANUARY-JUNE, 1896.

PHILADELPHIA:
Published by the Institute, at the Hall, 15 South Seventh Street.
1896.

T
1
F8
v.141

621332
24 10 55

JOURNAL OF THE FRANKLIN INSTITUTE.

Vol. CXLI.—January-June, 1896.

INDEX.

Acetone. (*See* Asphaltum.)
Acetylene and insurance 474
calcium carbide and 477
Alkaloids, vegetable, acidimetric estimation of. (Kebler) 141
Aluminum, electro-metallurgy of. (Richards) 357
industry, growth of 231
(*See* Sodium.)
Annual review of science and industry. (The Secretary) 148
Anthion, a new oxidising agent 236
Asphaltum, on the use of acetone in the technical analysis of. (Peckham) 219
Automobile vehicles. (Salom) 278

Battery. (*See* Storage Battery)
Bennett, Maurice. The evolution of the storage battery 296
Bergami, Francis. A source of error in the determination of phosphoric acid by the citrate method 383
Standardising of normal acid by borax 386
Birkinbine, John. Engineering on the Great Lakes 428

BOOK NOTICES:
Richards. Aluminum 78
Abbott. Electric transmission of energy 78
Bolland. Founding 157
Fletcher. Assaying, etc. 157
Shenstone. Liebig 157
The Horseless Age 157
Ostwald-Walker. Physico-chemical measurements 158
Merriman. Hand-book for surveyors 158
Webb. Engineering instruments 159
Pence. Stand-pipe accidents 159
Wolcott. Annual Report U. S. Geological Survey 237
Klein. Lehigh University school of mechanical engineering . . 237
Woolcombe. Physics 238
Riehlé. Quarterly digests, etc. 238
DuBois. Mechanics, kinematics 238

Jacoby. Plain lettering 395
Holman. Rules and logarithms 395
Flather. Rope driving 396
Peters. Modern copper smelting 398
Siebert. Stone cutting, etc. 398
Grimshaw. Shop kinks, etc. 399
Seaton-Roanthwaite. Marine engineering rules and tables . . . 399

Borax, standardising normal acid by. (Bergami) 386
Building, buildings. Modern office building. (Ferree) 47, 115
fire-proof, defects of 75
stones of the United States. (Day) 98

Calcium carbide and acetylene 477
Canal, Drainage, for Chicago 72
Nicaragua, report of commission of engineers 230
Carbide-acetylene problem 390
Carbides, new, of iron. (Benneville) 77
Carbon in the electric arc, condition of 154
Carter, Oscar C. S. A ferruginised tree 227
Chicago drainage canal 72
Christie, James. Structural steel 33
Citrate method. (*See* phosphoric acid.)
Color photography, Joly's process 479
Commerce and deepwaterways. (Haupt) 81, 171
Cooper, John H. The Worthington cooling-tower for the continuous use of condensing water 417
Corn-pith cellulose, Marsden's. (Nixon) 161

Day, Wm. C. Building stones of the United States 98
Delany, Patrick B. A new system of machine telegraphy 1
Diacetyl, on the oxidation of. (Keller and Maas) 224
Dolbear, A. E. Mechanical conceptions of electrical phenomena . . . 451
Drought, effect of, on river traffic 155
Duncan, Louis. The future of electricity in railroad work 401

Electric arc, the condition of carbon in the 154
current, action of, on fused sulphides 73
incandescent lamp is Edison's invention 230
light, Tesla's new 478
railway conduit, in winter 388
railways, under-surface 75
tanning 393
Electrical phenomena, mechanical conceptions of. (Dolbear) 451
Electricity in railroad work, future of. (Duncan) 401
Electrolysis, damage caused to water-pipes 235
modern theories of. (Richards) 192
Electro-metallurgy of aluminum. (Richards) 357

Engineering notes 234
    on the Great Lakes. (Birkinbine) 428
    tools at Pompeii 233

Falconnier's blown-glass bricks 76
Ferree, Barr. The modern office building 47, 115
Ferruginised tree. (Carter) 227
Filtration of city water supplies, with discussion 322
"Fire-proof" buildings, defects of 75
Flying machine, Langley's experiments 475
Fly-wheel made of wire 156

FRANKLIN INSTITUTE:
    Proceedings of stated meetings, December, 1895, to May, 1896, ... 79, 160, 240, 320, 400, 479
    Board of Managers. Resignation of J. C. Trautwine, Jr 79
    Election of C. Hartman Kuhn 79
    Election of W. N. Jennings 400
    Annual election of officers 80, 160
    Voting by letter-ballot decided to be inexpedient 240
    Boyden premium. Adverse report on a memoir submitted for the 399
    Resolution in favor of filtration of water for city supply 320
    Invitation to participate in the Mining and Geological Congress at Buda-Pesth 479
    Resolutions respecting the distribution of bound volumes of United States patents 480
French universities, removing of restrictions 479
Fuse-metals, inherent defects of, etc. (Harrington) 464

Gelatine, solidified 394
Glass bricks, Falconnier's 76
    solders for 393
    writing on 236
Graphics of thermodynamic law. (Thurston) 27

Harrington, Walter E. Inherent defects of fuse metals experimentally considered 464
Haupt, Lewis M. Commerce and deepwaterways 81, 171
Houston, Edwin J. and Kennelly, A. E. The Röntgen rays, with discussion 241

Iron and steel production, American 391
        rustless coating for 393
    new carbides of. (Benneville) 77

Japanese swords, metallurgical and other features of. (Lyman) 13
Jenkins, C. Francis. The phantoscope 80

Kebler, Lyman F. Acidimetric estimation of vegetable alkaloids . . . 141
Keller, Harry F., and Maas, Philip. On the oxidation of diacetyl . . . 224

Langley's experiments in artificial flight 475
Leeds, Albert R., and others. Filtration of Philadelphia water supply. Discussion 322
Light, unsolved problems in the manufacture of 72
Lyman, Benj. Smith. Metallurgical and other features of Japanese swords 13

Maas, Philip. (*See* Keller.)
Marsden's corn-pith cellulose. (Nixon) 161
Mechanical conceptions of electrical phenomena. (Dolbear) 451
Mineral determinations, new heavy liquid for. (Penfield) 235
  production of the United States, 1895 392
Modern office building. (Ferree) 47, 115

Natural gas at Pittsburgh 234
Nicaragua Canal Commission, report of 230
Nixon, Lewis. Corn-pith cellulose, Marsden's 161

Obituary notice. HENRY BOWER 387
Office building, the modern. (Ferree) 47, 115
Outerbridge, Alex. E., Jr. Pending problems for wage-earners . . . 337

Peckham, S. F. On the use of acetone in the technical analysis of asphaltum 219
Phantoscope, The. (Jenkins) 80
Phosphoric acid, a source of error in the determination of, by the citrate method. (Bergami) 383
Photography, Joly's color photographs 479
Platinum. (*See* Vanadium.)
Pompeii, engineering tools at 233

Railways, electric, under-surface 75
Richards, Jos. W. Electro-metallurgy of aluminum 357
  Modern theories of electrolysis 192
  Separation of silver from gold by volatilisation . . 447
Röntgen, W. C. On a new kind of rays 183
  Pictures, stereoscopic. (Thomson) 381
  Rays, the, with discussion thereon. (Houston and Kennelly) 241
Röntgen's discovery, medical applications of 232
Rustless coating for iron and steel 393

Salom, Pedro G. Automobile vehicles 278
Self-propelling vehicles, test of 155
Silver, separation of, from gold by volatilisation. (Richards) . . . . .
Simplon tunnel 389
Smith, Edwin F. An argument for the filtration of water drawn from the Schuylkill River for domestic supply 322
Sodium in commercial aluminum 236
Soldering lead to lead 156

Solders for glass 393
Solidified gelatine 394
Steam pipe, new 156
Steel, structural, (Christie) 33
  Bessemer, ingots and rails, production of in the United States in 1895 231
  wool 392
Stereoscopic Röntgen shadow pictures. (Thomson) 381
Storage battery, the evolution of, with discussion. (Bennett) 296
Sulphides, fused, action of the electric current on 73
Swords, Japanese. (Lyman) 13

Tanning, electric 393
Telegraphy, Delany's rapid machine system 1
Tesla's new light 478
Theories of electrolysis, modern. (Richards) 192
Thermodynamic law, graphics of. (Thurston) 27
Thomson, Elihu. Stereoscopic Röntgen pictures 381
Thurston, R. H. Graphics of thermodynamic law 27
Tunnel, the Simplon 389

Under-surface electric railways 75
Universities, French, removing of restrictions upon foreign students . . 479

Vanadium and platinum, curious occurrence of 234

Wage-earners, pending problems for. (Outerbridge) 337
Wire fly-wheel 156
Worthington cooling tower, etc. (Cooper) 417
Writing on glass 236

JOURNAL

OF THE

FRANKLIN INSTITUTE

OF THE STATE OF PENNSYLVANIA,

FOR THE PROMOTION OF THE MECHANIC ARTS.

VOL. CXLI. JANUARY, 1896. NO. 1

THE Franklin Institute is not responsible for the statements and opinions advanced by contributors to the *Journal.*

THE FRANKLIN INSTITUTE.

Stated Meeting, November 20, 1895.

MR. JOS. M. WILSON, President, in the Chair.

A NEW SYSTEM OF MACHINE TELEGRAPHY.

BY PATRICK B. DELANY.

In telegraphy, as in nearly all other industries, there are two ways of working: by hand, and by machine. Naturally the hand method comes first. It was so in telegraphy, and it has continued with wonderful tenacity. Even now, probably 90 per cent. of the telegraph business of the world is done by hand. In America and England, it is by hand and sound. In all other countries, by hand and sight, although Belgium is just beginning to use the sounder. France, Germany, Italy, Austria, Spain, Russia, and, in fact, the rest of the world, use the Morse key, and a receiving instrument which records the dots and dashes in ink on a paper tape. There are, however, a number of through circuits operated by the Hughes system. Transmission is by keyboard, and the message is received printed on a tape, similar to the tape-printing system of Phelps, which is used in a small way in this country.

England may be said to be the only country using machinery, to any considerable extent for the operation of its telegraphs. It employs the Wheatstone system. This is of English origin. Its inventor was knighted for it, and deservedly so, for it is a great system. In its operation, messages are first punched on a tape, which, in effect, becomes a stencil, taking the place of the operator's hand manipulation. This punched strip is passed through a transmitting machine run by weight and clockwork, and, as impulses are sent wherever there is a hole in the paper, the dots and dashes go into the line with perfect uniformity and at great speed.

The receiving instrument records these dots and dashes in ink, on a tape, as in the case of hand transmission.

This receiver, however, will record ten times faster than the fastest operator can send by hand, hence the advantage of machine transmission. And again, a machine can be made which will transmit ten times faster than the ink recorder will receive, hence the necessity for a quicker recorder than the inking machine. The Wheatstone receiver comprises clockwork, which pulls the paper tape at a rapid rate; and an electro-magnet, the armature lever of which, at its point, alternates between an ink well and the moving tape, making dots and dashes in response to the impulses coming over the line. The rapidity with which a current coming over a long circuit can be made to move this ink-marking lever determines the speed of the Wheatstone system.

It is claimed that, experimentally, 600 words per minute have been recorded. This would require the armature lever to touch and mark the moving tape 200 times per second.

The practical speed of the system over an ordinary circuit is about 200 words per minute. Apparently, the limit of rapidity of electro-mechanical movement at a distance has been reached, notwithstanding that the impeding effect of self-induction in the electro-magnet itself has been almost completely overcome by the use of the condenser shunt, for there is still the inertia of the moving armature and retardation of the line to be taken into account.

For higher speed at the receiving end of a line, *electrolysis* seems to be the only recourse. It is at least ten times quicker than the fastest electro-magnet, which is to be found in the latest Wheatstone receiver.

Alexander Bain was the first to introduce chemical telegraphy. He turned to account Humphrey Davy's discovery that by electricity a record could be made on paper saturated with certain chemicals.

Now, while Bain's idea was greatly in advance of the necessities of the time, his apparatus was not equal even to the very limited requirements of forty years ago.

The Wheatstone system, with influence and ability behind it, occupied the field and was improved from time to time, to keep pace with the increasing demands for higher speeds, until five or six years ago, when the limit was reached; nor is it likely that this system can ever be made to do any more than it is now doing.

The chemical system has been beset by many drawbacks. It never had a practical perforating machine. The transmitting instrument was very defective, and in Bain's time the way of overcoming "tailing"—or the running together of the dots and dashes on the receiving tape—caused by retardation of the line, had not been discovered. Consequently, chemical telegraphy in the early days, and even up to about 1870, was a very slow system indeed. It was very unpromising until the discovery, I think, by one of the Varleys, that an electro-magnetic shunt around a chemical receiver, would, by its opposing current of self-induction, clear out the tailing or shading between signal marks on the chemically saturated tape. Previous to this discovery, when anything like high speeds were attempted, the dots and dashes appeared as a continuous line.

This self-induction, however, has its drawbacks, for the reason that,in order to generate it,a large portion—certainly one-half of the signaling current—must be diverted from the recorder. Furthermore, while it improves the definition, this self-induced current has a tendency to clip or shorten the primary impulses, and, unless properly balanced, will appear as a reversal or negative record between the regular signals on the receiving tape. For these reasons it is best to get along with as little of the self-induction remedy as possible, consistent with legibility of signals.

If electrolysis could be brought about as quickly with small pressure as with greater electromotive force, the speed of transmission could be increased proportionately. The higher the force sent into the line, the longer it takes to disappear from the receiving tape. This would suggest the advantage of more sensitive chemical combinations for the paper, but then they might be affected by stray or induced currents from neighboring wires. The present formulæ seem to ignore all but the legitimate impulses coming over the line.

The susceptibility of the receiving tape depends on the speed at which it is running. If the movement is very slow, a very weak impulse will make a distinct mark. If the tape is running fast this plain mark will be drawn out, and will be very faint. It is a question of time and current. High speeds require fast-running tape, and the quickly passing chemicals require correspondingly higher electromotive force for dissociation or separation, so that the iron wire may be attacked and corroded, thus causing the mark on the tape. Shortness of application must be made up by increase of pressure.

Another very serious obstacle in the way of chemical, and, in fact, all machine or rapid systems, has been due to the current which discharges towards the sending end of the line after each signal impulse has been sent in. These outcoming currents are proportioned to the charge that creates them. When a dot is sent, the line is not fully charged, not as much so as when a dash is sent; therefore, the discharge after a dash is much greater than the discharge after a dot. It follows that the discharge from a dash, opposing the passage of a dot, hinders and neutral-ises it to a very detrimental degree. The simplest remedy for this trouble is to send no dashes into the line, making all signals of exactly the same duration, and thereby secure uniformity of discharge current as well.

The remaining important defect in machine telegraphy heretofore, was in the transmitter.

With the exception of the Wheatstone transmitter, which is entirely too slow for chemical telegraphy, all mechanical transmitters used or proposed have consisted of a revolving wheel over which the perforated tape was drawn. This wheel was connected to the transmitting battery. On top of the tape pressed a scraping finger, which was connected to the line. When a hole in the paper came between the line and the wheel, an impulse was transmitted. Contacts made in this way were very imperfect, and frequently missed altogether, on account of the collection of dirt and dust on the face of the wheel.

Having touched upon the leading obstacles in the way of practical high-speed telegraphy, I will now endeavor to explain and demonstrate how, in my opinion, these difficulties can be surmounted; and in doing so, I will take up, in their order, the three principal features of machine telegraphy, viz.: the perforator, the transmitter, and the receiving machine. You will observe that the improvements about to be described are both mechanical and electrical.

The Perforator.—This machine, as shown in *Fig. 1*, comprises three keys, dot, dash and space key; two electro-magnets for forcing the punches through the tape, and a step-by-step tape-feeding device, also controlled by an electro-magnet.

The operation is as follows: The ribbon is perforated in two lines, the holes in the top line representing dots; those in the lower line dashes. The letters are made of combinations of dots and dashes, preferably according to the Continental Code. The lower contacts of the three keys are connected to one pole of the battery, *L B*. The dot-key lever is connected to the punch magnet, *C;* the dash lever to punch magnet, *B;* and the space lever to space magnet, *A*. Obviously, but one key is pressed down at a time. The spacing magnet is in series with the dot and the dash magnets. To punch the letter *A*, the dot key is pressed down, magnet *C* forces its punch through the paper, and, at the same time, the lever of the space magnet is drawn down, and pawl *a* takes a new tooth in the ratchet wheel on shaft *F*. When the key is released and the circuit broken, the punch is raised out of the die and the strip is drawn a definite length by the sawtooth wheel *f*, and pressure wheel *e*. Then the dash key is operated in the same way, after which the space key is touched, which provides a space between the letter punched and the one which is to follow. Thus,

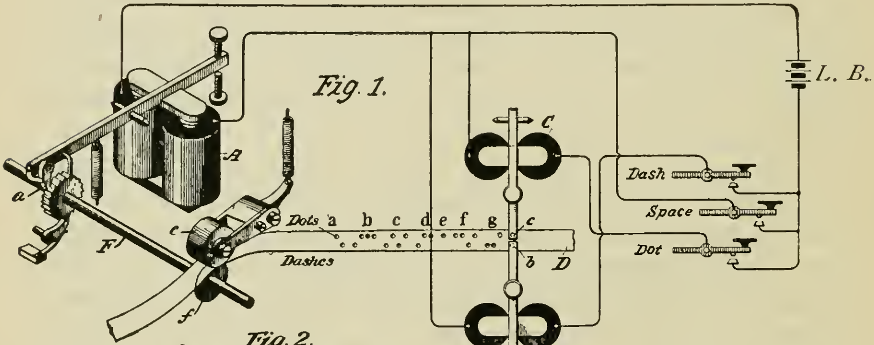


Fig. 1.

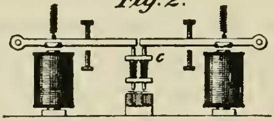


Fig. 2.

the space key is pressed down once after each letter, and three times after each word.

Perforating is no more laborious than working an ordinary Morse key, and the speed, with a little practice, will be fully up to the average of Morse transmission.

A side view of the punch magnets, their levers and punches, is shown in *Fig. 2*.

The Transmitter.—The transmitter, as shown in *Fig. 3*, consists of a paper-pulling device, represented by roller *R*, and the two pairs of wire brushes pressing toward each other above and below the tape. The top brushes are electrically one, and are connected to the line *L*. The bottom brushes are insulated from each other, one being connected to the positive, the other to the negative pole of the main transmitting battery, *MB*. This battery is connected to earth at its middle.

The paper tape separates the brushes, when a hole in the top line is drawn between the brushes, a positive impulse, representing a dot, is sent into the line. When a hole in the lower line is drawn between the other brushes, a negative current, representing a dash, is sent.

In this manner all the dots and dashes on the tape are transmitted.

The brushes are made up of six wires each, so that six contacting points come together at each perforation, rendering failure impossible and insuring perfect uniformity in the quality of the impulses. The ends of the brushes are kept bright and clean by the edges of the holes, and a pressure may be put on them which will insure electrical contact with the tape moving 30 feet per second, or at the rate of 8,000 words per minute, or over 2,500 impulses per second.

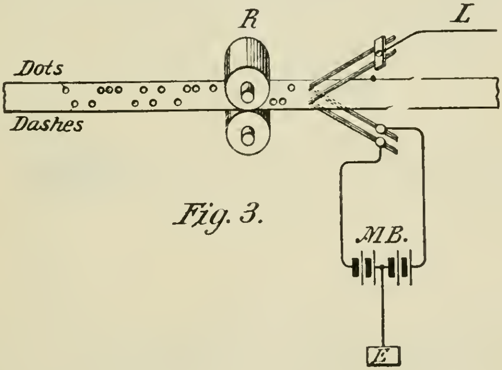


Fig. 3.

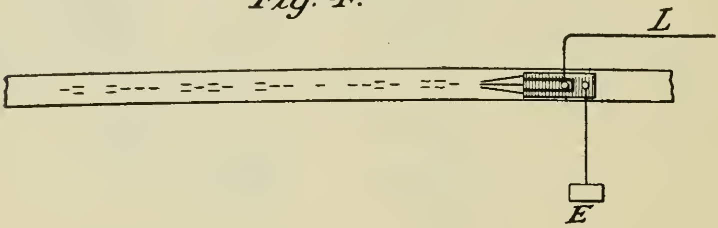
In this form of transmitter there are no movable or adjustable parts, no circuit wheels to get dirty, no loose or lubricated contacts. An electric motor is used to pull the perforated tape.

It will be seen that as no dashes are sent, but only dots, which, owing to their position on the tape, *represent* dashes, the impulses are of uniform duration, and the line is not more heavily charged at one time than another; and consequently, the discharge is also uniform, and the signals on the receiving tape are correspondingly regular.

The Chemical Receiver.—The receiver is shown in *Fig. 4.* It comprises a wheel over which the chemically moistened tape is drawn under three thin iron wires which press lightly on top. The two outside wires are electrically one, and are connected to earth. The middle wire is insulated from the others, and is connected to line.

When the brushes of the transmitter drop into a hole in the dot line, a positive current is sent, and a dot is marked in the track of the middle wire of the receiver. When the transmitter brushes drop into a hole in the lower or dash line of perforations, a negative current is sent, and a dot is marked in duplicate on the receiving tape, one in the track of each of the outside wires. This impulse is but a dot in duration; but as it is meant to represent a dash, it must have something to distinguish it from the dot signal; therefore, the current is forked or divided on the receiving tape, so that all dashes are in the form of double dots, while the dots proper are single, and occupy the centre line on the tape. It will be understood that the chemically moistened tape forms the circuit between the center wire and the outer wires of the receiver, or between the line and earth; and that all positive currents come over the line and mark in the track of the middle wire, while negative currents come from the earth, and mark in the track of the forked contact, forming double dots, which are recognised as dashes.

Fig. 4.



In this way, no matter how bad the "tailing" may be, it is impossible to mistake a dot for a dash, or to connect them together erroneously; neither is it necessary to have definition between successive dots or dashes. The length of the composite, single or double mark, determines at once the number of distinctive marks intended. In cable signaling, there is practically no definition as to the number of impulses in the undulations of the ink line. The proportion determines. Of course, in this system of perfectly straight marks in distinctly different lines, translation is much easier.*

The specimens of record, *A* and *B*, seen in *Fig. 5*, illustrate this most important feature. *B* shows the word "telegraphy" with clearly defined individuality of each dot and dash. *A* shows the same word without any definition whatever, but, notwithstanding, the word to a practised eye is just as plain in this form as the other. It is safe to say that, with a few weeks' practice, the transcriber would not look for definition in signals.

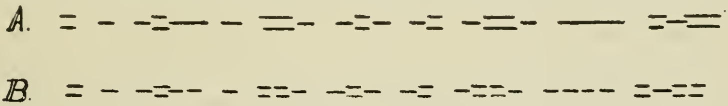


FIG. 5.

It will be clear, then, that a length of line, or rate of speed, which would render signals by the ordinary dot-and-dash method utterly illegible, would be perfectly practicable with this method.

Having dealt at considerable length with the technical side of the subject, I must be brief in referring to the commercial possibilities of machine telegraphy.

A perforator will prepare messages as fast as a Morse operator will transmit by hand. The machine transmitter will send, between New York and Philadelphia, over a common iron wire, at least 1,000 words a minute, or as much as can be sent over 50 wires by hand, simplex. If quadruplex is used, 15 wires will be required to compete with the machine system on one wire. With a copper wire of 500 pounds to the mile, the machine system will carry 2,000 words per minute, or as much as 30 wires worked quadruplex.

---

*[At this point, Mr. Delaney made several experimental transmissions through an artificial line of 800 ohms resistance, and 2 microfarads capacity, or the equivalent of an ordinary iron telegraph wire between New York and Philadelphia. Perfectly legible records were obtained at a speed of 1,200, 1,800, and finally 2,400 words per minute, as timed by Mr. Thomas Shaw, M.E., and others.—The Secretary.]

The general introduction of this system for carrying correspondence would require but one or two wires between large cities, and a way wire for smaller places. Any number of towns up to the capacity of the wire could be communicated with in rotation, and messages exchanged. Beginning at one end of the line, each station would clear out with all the other stations, and would send to the main distributing and collecting office on the circuit, messages for points not on the wire. In this way each office would have what would practically be a half-hourly electrical mail service. Telegraph letters would be perforated as fast as they were handed into the office; so that when the time of each office came around, the entire lot would be ready for transmission.

Two wires would carry all the correspondence now done between New York and Philadelphia; one would accommodate New York, Baltimore and Washington; New York and Boston would require one wire, and one would suffice for way stations. Two through wires would be necessary for New York and Chicago, and so on.

This plan, carried out so as to cover the country, would speedily supplant the present mail service for all correspondence of any urgency, and would take from the present telegraph and telephone companies a great portion of their business, not of sufficient urgency to warrant the comparatively very high charges, when a service equally as good is available at one-tenth of the cost.

Business houses having a large correspondence, and newspapers, would take advantage of the very low rate for simple transmission of dispatches handed in already perforated, and to be delivered on the received strip without translation. Such service would probably not cost more than 5 cents for 100 words between New York and Philadelphia, exclusive of delivery charges, or 10 cents between New York and

Chicago. For regular patrons, carrying on extensive correspondence, special arrangements could be made for delivery, or the parties themselves could send to the telegraph office at stated times, and receive their dispatches from their box, after the plan of the present post-office system. These means, with the regular post-office delivery, would be the most satisfactory and least expensive for this service, the object being simply to substitute the wire for the railway train for conveying correspondence from one point to another, leaving the collection and delivery to the present very efficient and reliable post-office service. In no other way could very low rates be maintained. There would be no branch offices.

Messages would be sent or mailed to the central station, located close to the general post-office, in each city. Everything addressed to the central station of the company would be dropped in a special drawer, which would be constantly emptied by the telegraph company's collector. In this way a telegraph letter arriving at the general post-office would immediately be taken to the telegraph office, perforated, and transmitted to its destination, where it would be dropped in the post-office for delivery, thus practically eliminating the time now consumed in the railway journey.

DISCUSSION.

MR. THOS. SHAW:—Do you derive any advantage from the use of reverse currents?

MR. DELANY:—Only so far as they admit of placing the dots and dashes in separate lines on the receiving strip. If the reversals were regularly alternating, of course, there would be a gain in clearing the line; but they are not, since all the dots are sent from one potential, and all dashes from the other. Therefore, several impulses of the same polarity, varying in number from one to four, follow each other; but, as already pointed out, the composite character of these marks at great speeds does not in any way interfere with translation of signals; the dashes being in double and the dots in single lines, cannot be merged, as the length—in the absence of definition—determines clearly the number of dots or dashes in the marks. A glance at the strip is sufficient to realise the difference between one, two, three or four dots or dashes, the means of verification by comparison being always before the transcriber. It is well known that in cable telegraphy—the most accurate of all signaling, indeed, marvellously so, when the unmeaning and unpronounceable code words are considered—there is, as already stated, little or no definition, the number of dots or dashes being known by the dimension of the curve in the undulating lines made by the siphon recorder. In my system, definition never entirely ceases; but were dots and dashes all in the same line, as heretofore, translation would be rendered unsafe before half the present speed could be reached.

MR. E. A. SCOTT:—Has this system ever been tried on a regular line?

MR. DELANY:—Yes. On the 13th of October, in this city, a trial was made over a wire to Harrisburg and return, 216 miles, principally of No. 11 copper wire, 130 pounds per mile, and about 25 miles of ordinary iron wire. The speed reached was 940 words per minute, perfect record. I have some of it here. The weather on that occasion was very stormy and the leakage of current very great.

So far as resistance is concerned, this circuit was about twice as long as a line of 850 pounds per mile of copper would be from New York to Chicago, but the electrostatic capacity was very much less. The electromotive force used was 120 volts, or about one-half the pressure used for quadruplex (Morse) working.

(ABSTRACT.)

METALLURGICAL AND OTHER FEATURES OF JAPANESE SWORDS.*

By Benjamin Smith Lyman.

The lecturer was introduced by Mr. F. Lynwood Garrison, Professor of Economic Geology and Metallurgy in the Institute.

JAPANESE SWORDS.

Forging.—The smith carefully selected and tested his steel or iron; for, although the earliest swords were made of copper or bronze, only steel and iron have been used for many hundred years past. Preferably steel alone was used, but sometimes one-third, one-half, two-thirds, or even more iron was intimately united with the steel by welding bars together. The metal was generally Japanese, but in the last 300 years European metal has occasionally been used, and then sometimes marked as metal of the "Southern Barbarians."

In the all-steel or "pure-make" style of forging, as distinguished from the "mixed-make," several flat pieces of steel amounting all together to something over a quarter of the weight of the sword, are placed one on another, with an iron rod welded as a handle to the lowest one, and are heated in the fire. To prevent the conversion of the steel into soft iron by "burning," or oxidising its carbon, and also to keep the surface of the metal free from iron oxide that would be injurious if hammered in, the steel is never heated without being previously covered carefully with a thin wash of refractory loam and sprinkled with straw ashes, an ingenious precaution that is unknown in Western countries

---

* Abstract of a lecture delivered before the Franklin Institute, Friday, November 8, 1895.

The metal, too, must be kept scrupulously clean and never touched with the hand, as the least sweat will hinder perfect welding and leave a flaw visible in the sword.

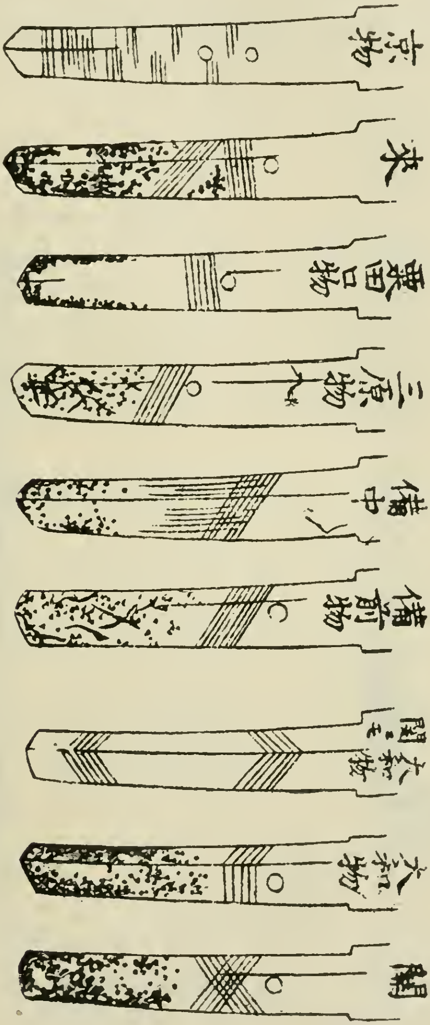
The little pile of steel plates is hammered on the anvil into a single flat bar, 6 or 8 inches long, by a couple of inches wide, and perhaps ½ inch thick. The bar is then doubled over, end to end, heated again and hammered out to a bar of about the same size as before; then doubled again, reheated and hammered out once more; and so on, until it has been folded and hammered out fifteen times. Then the iron handle is cut off. In that way three more such bars are made. The four bars are then welded upon one another into a somewhat larger, thicker bar, and this again is five times doubled over and hammered out to about the same dimensions. The object of all this folding and hammering out is, of course, to secure perfect homogeneity with a thoroughly fibrous structure.

It is readily seen that an immense number of layers has been produced thereby. The first doubling gives 2, the second 4, and so on, 8, 16, 32, 64, 128 (or more than 125), over 250, 500, 1,000, 2,000, 4,000, 8,000, 16,000, and the fifteenth over 32,000 layers. The four small bars together would have then over 125,000, and the five other foldings would give over 250,000, 500,000, 1,000,000, 2,000,000, and finally over 4,000,000 layers.

The polished sword has consequently fine lines like the grain of wood, and they are called the sword's hide or skin; and are distinguished by names according to the form, such as: straight-grain-skin, board-grain-skin, pear-skin, like a halved pear, pine-skin, ragged like pine bark.

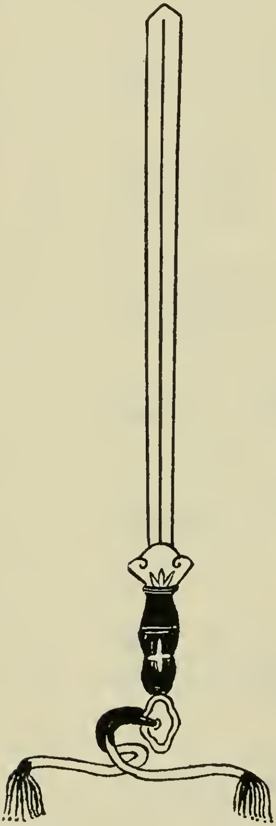
When iron is used along with the steel, there are several ways of combining the small bars to make the larger one; for example: a steel bar between two iron ones; an iron bar welded on a steel one, and folded over lengthwise with the steel inside; a bar of iron and one of steel welded together along the edge, and covered by an iron bar as wide as both together, and then the whole folded lengthwise so as to bring the steel along the middle of one edge; and eight or ten or more ways, down to simply applying an edge of steel to a back of iron, a very inferior method, but quickly done and common in war times.

The resulting bar of steel, or steel and iron, is then, with

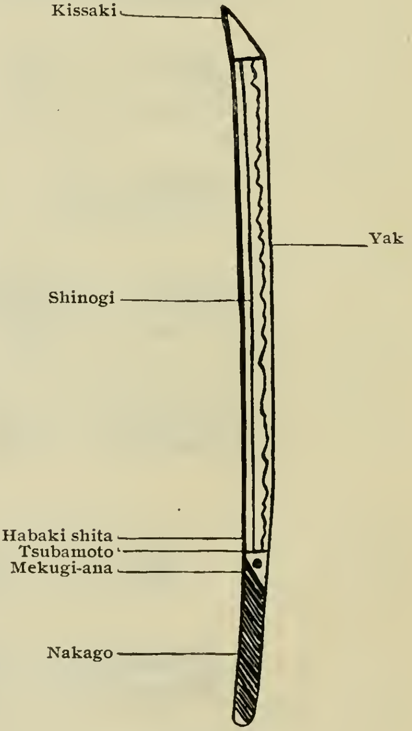


File Marks.

frequent and partial heating, hammered out to the length of the desired blade, somewhat curved according to the final shape; and both ends are cut off, where the metal is inferior. The point is formed, and, by hammering thinner towards the edge the right breadth is given, and the blade gets its rough shape, not by any pattern, but by the smith's practiced skill and true eye. The curve depends on the smith's taste, or the future owner's; or, in certain ceremonial swords, is prescribed by rules of etiquette. The rough blade is scraped off with a kind of metal draw-knife, and filed, and is then ready to have its edge hardened, or to be tempered.



Tsurugi.



Katana.

The shape of the file and the direction of the lines it makes have, of course, nothing to do with the quality of the sword, but as the lines remain permanently on the tang, under the hilt, they serve in some degree for the identification of the sword-maker, and special names have been given to different arrangements of them.

The shapes and sizes of swords are various, and give rise to many names and ways of classifying.

The *tsurugi* is the primeval sword of Japan, not used for many centuries past. It is straight, two-edged, 28 to 40 inches long, 2½ to 3 inches wide, and in the middle ⅗ inch thick, with a short point; and is more for cutting than thrusting.

The one-edged swords, called in general *katana*, are also mainly for cutting, and are made more effective by being curved. The advantage of protecting the body by the sword kept before it, in a thrusting style of fencing with a straight, pointed sword, appreciated in Europe from ancient times, seems never to have been comprehended in Japan and Asia generally, where the defence depended rather on heavy armor.

The one-edged swords are the following, according to their length, beginning with the longest: *tachi*, strongly curved, hung by two cords or straps, formerly worn by generals as a mark of their rank, but now somewhat rare. *Katana* proper, some 30 to 33 inches long. *Wakizashi*, some 18 to 20 inches long, with a guard. *Tantô* (short sword), some 11 or 12 inches long. *Yoroi-tôshi*, or mail piercer, about 7 inches long, with two edges for about half-way from the point. *Kuwai-ken* (bosom sword), about 6 or 7 inches long, worn by ladies. *Kogatana* (little *katana*), or paper-cutter, a small knife inserted in the outside of the scabbard of many short swords.

Several other forms are distinguished by less common names; and some names indicate special modes of wearing a sword rather than its form. Swords are also classified according to the shape of their main cross-section, to the form of the back, to the grooves cut in the blade, and to the general curve of the blade.

Tempering.—In the tempering, the Japanese process is again peculiar, and particularly ingenious and advantageous. We must remember that steel, when heated red-hot and suddenly cooled, becomes hard, brittle and elastic, to a greater or less extent, according, not merely to its composition, but to the degree of the heat and the suddenness and degree of the cooling. When this hardened steel is heated again and allowed to cool slowly, it becomes soft and malleable once more, in a degree proportioned to the heat just given, and that is called "softening" or "annealing" the steel. Tempering steel implements generally means a combination of first hardening, and then, by annealing, reducing the hardness to the desired temper; that is, to the amount of hardness that best fits the implements, each according to its use, for resisting wear and tear, with the least possible brittleness, at the same time. Commonly, with us, a sword is hardened by heating it to a dull red heat, and then plunging it, point downwards, into a tub of cold water. Then it is drawn through the fire, until the previously polished surface acquires a blue tint from the thin, superficial, iridescent film of iron oxide that becomes thicker and changes color according to the degree of heat. Then the sword is allowed to cool. The hardening expands the steel, but more rapidly on the surface than in the interior, occasioning strains; and so, too, with the corresponding contraction caused by the annealing. Hence, the implement is apt to crack, split, bend or "buckle," or get out of shape, and special precautions must be taken to keep or restore the proper form.

In Japan, the temper is given by a single process. What is desired for the sword is a hard edge, capable of being keenly sharpened; but a body and back far less brittle, though not soft, flexible and inelastic, like iron.

The blade is first coated with loam $\frac{1}{8}$ inch thick, a loam that bears the heat well, mostly a red earth called rust-mud, mixed with an equal quantity of the finest powdered river sand and one-tenth of the finest powdered charcoal, or with other things. Many smiths make a secret of the composition. Before the loam coating is quite hard, a narrow streak of it along the edge of the blade is carefully removed with a bamboo rod, so as to leave the edge bare. The rest is dried before the fire.

The smith then holds the blade in his right hand, by the tang, with pincers, and thrusts it horizontally, edge downwards, into the hottest part of a strong fire of pine charcoal of a special quality, called forge-coal, while his assistant—or he himself, with his left hand—regulates the heat by the bellows. The blade is moved slowly backwards and forwards, in order to be uniformly heated throughout its whole length. The part next the tang is often drawn gently out of the fire, so that the master's practised eye may judge, in the carefully closed and darkened smithy, when the right degree of heat has arrived. It comes in a few minutes, and the sooner the better, so that the loam covering may not have time to get overheated through and through.

The blade is taken from the fire and plunged immediately into cool, lukewarm water, of a temperature and during a time determined by the smith. Each smith has his own way. The sudden chilling hardens the bare edge, and makes it capable of great sharpness, though very brittle; and the color becomes whiter than the darker, bluish tinge of the rest of the blade. The loam protects the rest of the blade from too great heat in the fire, and now from too sudden chilling in the water; and so the desired temper for the body of the sword, sufficient hardness, stiffness and elasticity, with toughness, too, is obtained by the same operation that gives the still greater hardness to the edge.

The narrow strip left bare at the edge for hardening is called the baked-edge (*yakiba*), and is not always of the same breadth or shape, but differs according to fancy, and thirty or more varieties are distinguished by special names. A very broad baked-edge is not desirable, for too large a part of the blade would be brittle. Consequently, a narrow, straight hardened edge, or a simple irregular one is generally preferred and the commonest. Among other forms there is no preference, and they show nothing of the quality of the sword. They depend on the smith's or the owner's fancy, and somewhat on fashion, and in times of long peace the more complicated forms are apt to be preferred. In some degree they help to identify the maker; for, though celebrated smiths used various forms, connoisseurs know which forms each master most used. The bounding line of the hardening at the point of the blade gives rise to eight or more different forms and names.

The expansion of the edge from the sudden cooling in the bath causes a curved sword to bend somewhat further, and to a degree dependent partly on the manner of dipping the blade into the water. A straight sword is plunged vertically downwards. A curved one is let down horizontally into the water, with the edge down, either suddenly or slowly, either evenly or with the point slightly lower at first and rising from the water as the tang goes in. If the blade curves too much, or, by bad holding, bends sidewise, it can be heated and hammered again, but with no benefit to the quality.

Smith's Finishing.—The tempered blade is carefully cleaned and roughly ground on a coarse stone. The smith then, for the first time, sees whether the blade is a success or not. If it be satisfactory, he next cuts the grooves, if any, with a steel graving tool, giving an exactly semi-circular cross-section. The grooves lighten the sword, and are found in some of the oldest specimens.

Many smiths adorn their swords with engraving, especially with dragons, gods, flowers, Chinese or Japanese characters and Sanscrit letters, or the name of the sword itself, if it have one. But, as such engraving sometimes serves to conceal blemishes in the blade, it is not always liked by connoisseurs.

The smith drills a hole through the tang for the bamboo or metallic peg that holds the hilt on. He sometimes cuts his name on the tang, and the custom existed already about 1,200 years ago, but has often been neglected. Poor swords commonly have no maker's name; but, again, some famous makers would not put their names on, because, they said, anybody that understood swords would recognise theirs by the quality. With the name on the tang are often given the title and the date, and sometimes the owner's name and the name of the sword itself, if it already had one when forged; and, again, poems, pithy sayings, or wishes. It should be remembered that inscriptions of makers' names are sometimes counterfeited.

The most famous sword-maker was Masamune (about A. D. 1290); and, next, his pupil, Muramasa (about 1340); then Yoshimitsu (about 1275); and Munechika (about 990). Of Masamune's swords it is often said they are so fine they will cut a hair falling in the air, or cut in two the very hard-skinned adzuki bean as it falls; or, if held in a stream, will cut in two a sheet of paper floating down. The swords of Muramasa are said to be so finely tempered as to cut hard iron like a melon.

The first reported human swordsmith is said to have been Amakuni, of Uda, in Yamato (about 60 B. C.); but the oldest known swords, some of them still extant, were made by another smith of the same name and place, about A. D. 702. The Emperor Gotoba (1184) greatly favored the art of sword-making, and even practised it himself. In general, the art flourished in times of many wars, particularly in the thirteenth and fourteenth centuries, the age of the best swords. For the past 300 years of peace mainly, skill in sword-making has declined. Old swords, so-called, date from before that time, that is, before 1603.

Grinding.—The final grinding and polishing of swords is a trade quite distinct from the smith's. The grinder holds the blade horizontally before him in both hands, protected by cloths wound about it, with a narrow portion left uncovered between. He rubs it back and forth on a small whetstone well wet with water, moving by degrees through the whole length of the blade, except the tang; first, with coarser stones, then with finer, up to four, six or eight, for ordinary work, or, for very fine work, fifteen stones; giving to it many days and even weeks, as well as great patience, skill and care. The cross-section of the blade should be left convex on both sides; otherwise, the edge is too easily broken.

Lastly, the blade is polished with a polishing stone, and with a stone powder as fine as flour, or with the finest powdered steel, forge cinder and oil, as also with a small, round rod of wrought iron, until the polish is perfect. Winter is preferred to summer for polishing, as newly polished swords are thought to rust too easily in summer.

Swords ought to be carefully oiled and rubbed now and then, as often as twice a year in Japan, and very valuable swords, perhaps, once a month. Otherwise, moisture in that damp climate condenses on them and causes rust. Above all, they ought not to be kept uncovered by a scabbard of some kind. For this reason they cannot well be displayed in museums. Every sword, in the course of years, needs a slight grinding, from time to time, and the selection of a good grinder is very important, and some grinders have great reputations.

Sword-grinders, with their close and protracted observation of swords in grinding, become almost incredibly skilful in detecting the signs of the quality of a blade, and in recognising the make of the numerous celebrated masters. The most famous connoisseurs belong to the sword-grinding family of Honnami, who have been the imperial sword appraisers for the past 550 years.

Not only do the shape of the blade and its point, the form of the limit to the hardened edge, and the file marks of the tang give indications of the origin of a sword, but it is astonishing how many clues are found by an extremely close examination of the surface of the metal, thoroughly homogeneous, close-grained and intractable as it seems at first view.

The more strongly the whitish color of the hardened edge contrasts with the bluish tinge of the rest of the blade, the better the metal and its forging; yet the limit between the two colors should not be hard and sharp, but softly bounded; and that is partly caused by a weak, cloudy glimmer in irregular spots (called *nioi*, vapor) along the union of the brighter hardened and the dark unhardened portions. Partly in the one, often to the very edge, and partly in the other, they are found in all blades, and only in a poor one are rare. They arise during the hardening, and vary in number and character according to the quality of the metal and of the forging and to the temperature of the last heating, and cannot be counterfeited. It is thought best they should not be uniformly scattered, but in thicker and thinner groups, like the clouds in the sky.

If the loam covering, while the blade is moved back and forth during the heating, becomes thinner in some spots or loose, so that the heat of the fire and subsequently the chilling of the bath work more strongly, there arise in the surface of the blade isolated, cloudy spots, called *tobiyaki* or *yuhashiri.* They cannot be produced on purpose, are rare, and are seen with satisfaction.

The "grain" on the surface of good swords should be soft and tender, "as if water rippled over the metal."

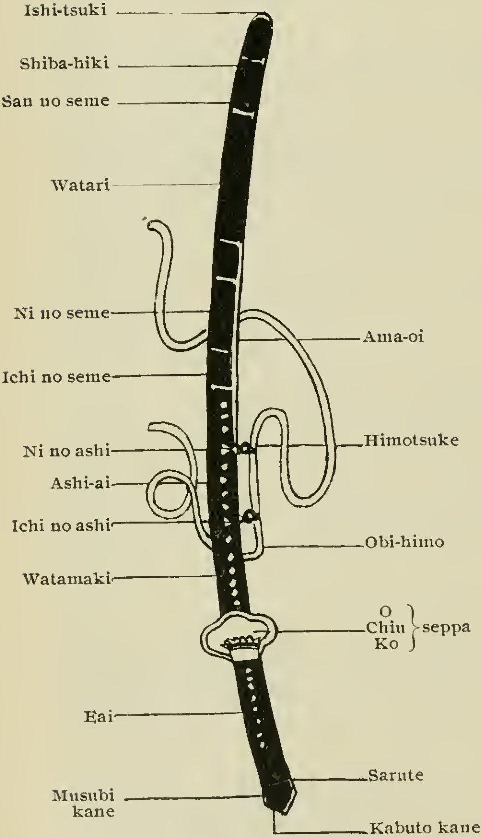
A certain degree of heat very favorable for the hardening, as well as especial success in the chilling, produces on the surface of the lighter colored, hardened edge minute shining points, called *nie.* According to some, they arise from bubbling in the water. They are often very difficult to perceive, and sometimes even a connoisseur requires a magnifying glass to discern them. They are reckoned a sign of good quality, and occur on most of the better blades, and especially in large number on Masamune's.

On many, though not all, good blades, and particularly on those of Bizen, but never on bad blades, there appears a weak glimmer, called *utsuri* (not to be confounded with the *nioi*), running parallel to the hardened edge inside the darker metal, and resembling "the colors of the rainbow alongside one another and the halo of the moon."

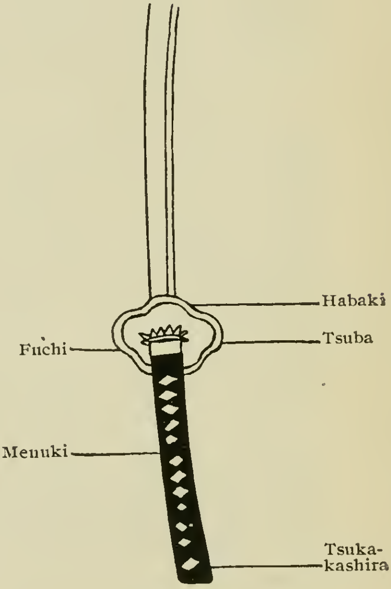
There are other signs still more difficult to detect; such as certain small cloud specks or points, and a narrow local glimmer along the boundary of the hardened edge, and extremely fine shining lines or rows of minute points in the *nioi.*

Neither the quality nor the quantity of any one of all these signs is decisive, but rather their combination.

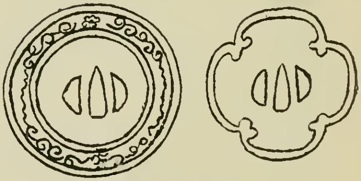
Testing.—The usual Japanese tests of a sword are on the human body; on corpses of beheaded convicts, or in the beheading; or by ruffians, on beggars and peaceable wayfarers; or even on a dog. But Hütterott, from whose elaborate account many of the foregoing facts about Japanese blades have been taken, in his zeal, tested some good swords on metal. With a blade of Mino he cut through, at one blow, without injury to the edge, five *tempô* coins piled one on another, in all a full $\frac{1}{2}$ inch thickness of bronze, and $1\frac{1}{4}$ inches wide. The same sword, struck upon a piece of hard wrought iron about $\frac{1}{4}$ inch thick and over $\frac{1}{2}$ inch wide, cut about $\frac{1}{8}$ inch deep and became notched. At a second stronger blow it cut about the same depth and broke in two at the point struck. A good Satsuma blade could only cut through four *tempô*, and broke at the third blow on the wrought iron, after getting large notches by the two other blows without cutting very deep; but an inferior Kiyoto sword, that could only cut through three *tempô*, endured three blows on the wrought iron.



Tachi.

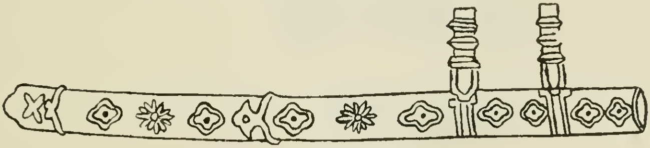


The Hilt (Tsuka).

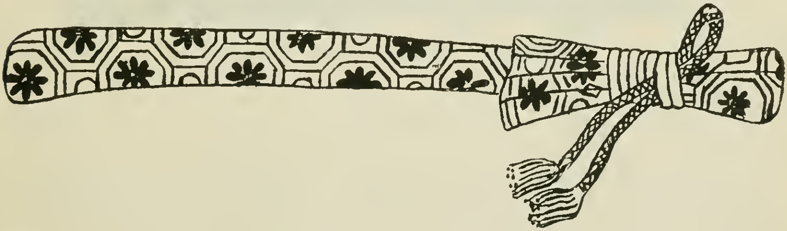


The Guard (Tsuka).

Mounting.—The finished blade may be mounted with a hilt, a guard, a ferrule and a scabbard, and the scabbard has certain fittings. The different parts have each its own name, and many of them are made highly artistic, particularly the guard, the metallic ferrules about the hilt and scabbard, and the metallic handle of the small knife inserted in the outside of the scabbard of many short swords. The knife is used as a last resource, to throw at the enemy in battle, or to cut his throat when he is down, and in peace is used as a paper-cutter. There is likewise a small metallic skewer inserted in the scabbard of those swords. It is used, in the heat of battle, to stick through the ear into the head of a slain enemy for future identification, or to carry his head for presentation to the victor's lord. Occasionally the skewer is split lengthwise into two parts, and can be used as chopsticks.



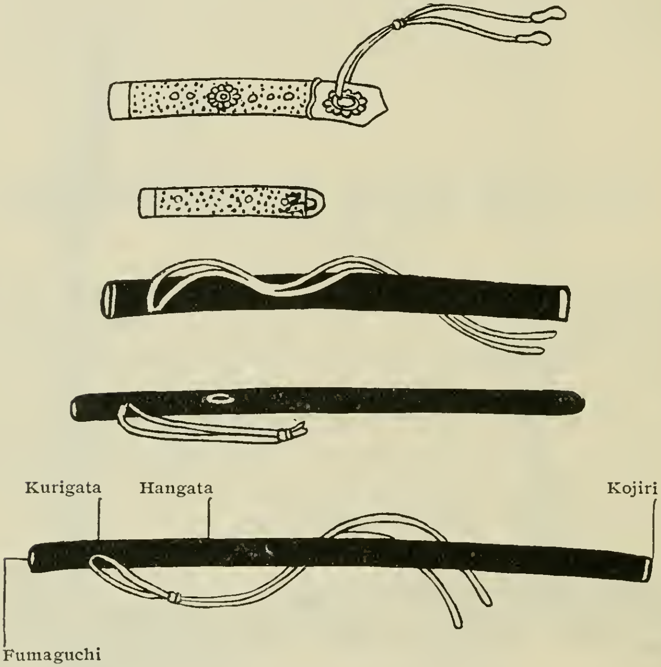
Scabbard for Tachi.



Brocade Bag over a Sword.

Etiquette.—The Japanese owner of the sword honored it highly, and many and minute were the rules of etiquette as to the way of treating and wearing it; and they were most strenuously insisted upon in former days, though they have now mostly fallen into disuse.

In fine, the Japanese sword must be admitted to be as beautiful and interesting an object as the processes of its manufacture are ingenious and skilful. Though not of the most effective form, it must always rank high among the weapons that will ever be needful as long as men exist who are naturally, or by training, so deficient in good-will or reason as to be amenable only to forcible restraint.



Scabbards (Saya)

[Japanese swords are discussed by the author more fully in the *Proceedings* of the Numismatic and Antiquarian Society, of Philadelphia, for 1890–91. The illustrations herewith, copied from Japanese books, have been kindly loaned by that Society.]

GRAPHICS OF THERMODYNAMIC LAW.

By R. H. Thurston.

The geometry of thermodynamics, and especially the graphics of heat and work transformations, may often be found to permit the employment of methods of elucidation of the principles of the science which are far more satisfactory to the average mind than are algebraic formulas. The latter are peculiarly difficult to follow, in the case of the majority of students of this subject, although absolutely logical, exact and positive; while the picture of the law, or of the fact represented by the graphical construction, often gives to the mind a thoroughly satisfactory idea, and a real conception of the physical quantities and the phenomena considered. The writer has, at times, employed such methods of representation in the development of the whole elementary basis of thermodynamics, as well as, frequently, in the discussion of special problems; some of which latter, in fact, while easily and readily treated by the graphical method, cannot be fully treated, at all satisfactorily, by any algebraic system.

In illustration, compare the method of application of the logical, syllogistic method, of the algebraic process, with the graphical system in the expression of the laws of thermodynamics, and in the deduction of the two principal forms of the "general fundamental equation." The logical process, as here referred to, is the following:

Propositions.—(1) The science of thermodynamics considers those phenomena of physics which involve only thermal and dynamic operations in mutual relations.

(2) In such phenomena the processes in action involve only displays of thermal energy, of dynamic energy, and of transformation of the one form into the other, in either direction.

(3) A given amount of energy being available and acting, it is a total consisting of two parts, thus:

$$E = H + W; \tag{1}$$

in which E is the total energy, and H and W and the two parts the thermal and the dynamic energy, of which it is made up in all cases, whether of supply or abstraction. Either term of the second member, or both terms, may be either positive or negative; positive indicating supply or gain, and negative indicating abstraction or loss of energy, by the system. Heat is always measured by the product $K_v d\,t$, of the true specific heat of the substance which is its vehicle and the range of temperature, in this case assuming an elementary change. Work, or dynamic energy, is always capable of being measured by an equivalent of the form, $p\,dv$, the product of the intensity of an unbalanced pressure in a fluid into the volume through which it acts, also here taken as elementary. Assuming a common measure of the unit of energy, as the foot-pound or the kilogram-meter, we may thus at once write out, as a deduction from the above principles, which, in fact, also assume the first law of thermodynamics, the quantivalence of energies, the general fundamental equation of thermodynamics, as above.

Stating the first law of thermodynamics as follows, the same algebraic expression may be at once written out:

Energy received or expended in either form is equivalent to the algebraic sum of that applied, in any thermodynamic operation, to producing change of temperature, and that applied to the production or reduction of work.

This statement is the verbal equivalent of the equation above.

Assuming, as the simplest case, the thermodynamic operation to be one in which heat is applied to the simultaneous increase of the temperature of a gas and the development of mechanical energy, by its expansion behind a piston, we have the above equation in the form

$$dH = K_v dt + p\,dv; \qquad (2)$$

which is the familiar first form of the general equation, as given by Rankine and by Clausius; the assumption being that the energy received by the gas may be supposed to take effect, first, in raising temperature, simply; secondly, in the development of mechanical energy, or the performance of work at constant temperature of working fluid. The work may either be that of internal molecular disturbance, or that of external displacement of an enclosing mass, as of "latent heat," L, or of sensible work, U.

Dividing the expenditure of energy into these several forms,

$$dH = K_v dt + dL + dU; \tag{3}$$

which is one of the forms given it by Clausius.

Comparing (2) and (3), it is seen that the factor p in the first measures the sum of the two forces resisting expansion in any mass, the one internal and cohesive, or molecular, the other external, confining pressure, as measured by a pressure gauge.

The second form of the general equation, as given by both Rankine and Clausius, comes directly from the first, thus:

In the "defining equation" of a gas, $pv = Rt$. When pressure is constant, as assumed in the construction of the first of the above forms involving t, the relation becomes $pdv = R\,dt$, and when t is constant, $p\,dv = -v\,dp$. Make t and p the independent variables, and it may be shown that

$$dH = K_p dt - vdp; \tag{4}$$

which is the second form of the general equation, as developed by both Rankine and Clausius. It is in the production of this form of the equation that a graphical method becomes especially satisfactory, as enabling the mind to follow the process, easily perceiving the relations of the quantities here variable. Rankine made much use of graphical methods in the discussion of thermodynamic and other problems, and his success is probably largely due to this fact. He has not, however, employed this system in the case here studied.

In the succeeding figures, let $A\ B$ represent a path along which the working fluid is carried, in any thermodynamic operation. Assume the action to take place by a series of elementary steps; as, *Fig. 1*, changing pressure at constant volume, on one isometric line, $A\,a'$, then changing volume at constant temperature, on the isothermal $a'a$, and again by ab' and $b'b$, and so on, until B is reached. It is evident that each elementary step, along the path AB, as Aa' or ab', is accomplished by expending quantities of heat energy at constant volume, measured by the product, for each unit weight of working fluid, $K_v dt$, and a quantity of work—no heat being accepted by the substance on the isothermal—measured by $p\,dv$, the equivalent of the heat-energy transferred from the source during the period of isothermal change. Thus, the whole quantity of heat energy demanded at each elementary step, ab, is

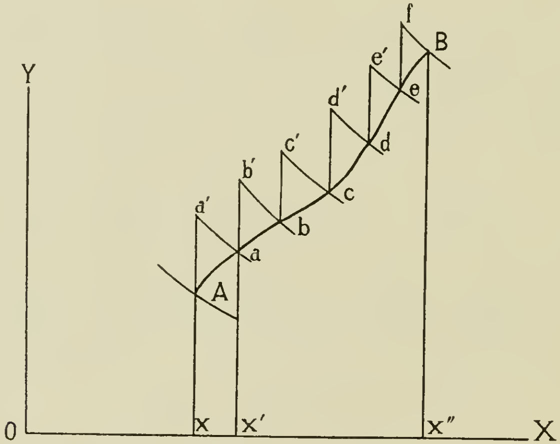


Fig. 1.—With V and T variable.

$$dH = K_v dt + p\,dv; \qquad (5)$$

which is the first form of the general equation of thermodynamics, and the method of its derivation, thus illustrated graphically, is easily followed.

In the second case, take the elementary steps in heat supply, as indicated in the second of these figures, first at constant pressure, from A to a, *Fig. 2*, at constant temperature from a to a', and so on. But, in the second of these steps, the work performed becomes negative, as reckoned in our algebraic work, and we have the second form of this equation:

$$dH = K_p dt - x''aa'x'. \tag{6}$$

But, since $a\,a'$ is an isothermal, in other words, an equilateral hyperbola,

$$y_a x_a = x_a{}' \, y_a{}' \, ;$$

and, deducting the magnitude $y_A x_A$ from these equal quantities, and the common magnitude $A\,f\,x'\,x$ from each of these differences, we obtain the equality, after adding faa' to both sides,

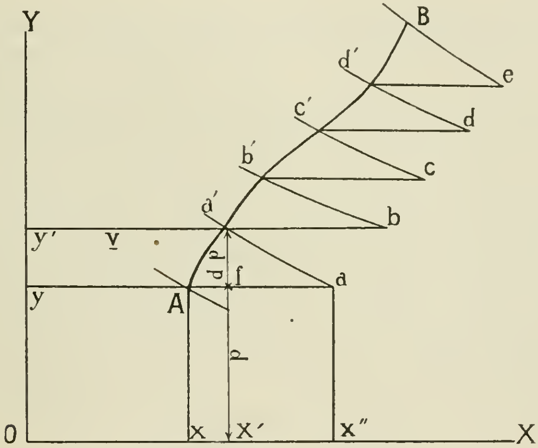


FIG. 2.—With *P* and *T* variable.

$$x'\,a'\,a\,x'' = y'\,a'\,a\,y\,;$$

in which expression the second member represents $v\,dp$.

Thus, equation (6) becomes

$$dH = K_p\,dt - v\,dp; \tag{7}$$

which is the second form of the general fundamental equation of thermodynamics, and its peculiar construction thus becomes readily understood.

It is thus possible to derive the expressions of Rankine and Clausius, in these two principal forms, by graphical construction and by reference only to the first law of thermodynamics.*

The second law enables us to extend the application of these equations to the more obscure cases of the non-gaseous substances, in which the existence of internal and sensible forces acting between adjacent molecules makes conception and application alike difficult. According to the second law of thermodynamics, as already seen,

$$p = t \frac{dp}{dt}; \tag{8}$$

the total force p, against which energy plays in the thermodynamic operations above referred to, is the sum of the sensible external pressure, p_e, of the fluid, measured by the pressure-gauge, and the internal and the insensible internal pressure p_i, due to the attractions among molecules, the cohesive force of the substance. The total p can be easily computed, though impossible of direct measurement, and thus, in all cases, it is practicable to secure a correct and manageable form of the above equation and its fellow, independently of the peculiar characteristics of the fluid, by first simply determining, as may easily be done, the value of the partial differential coefficients. These expressions thus become

$$dH = K_v\, dt + t \frac{dp}{dt}\, dv; \tag{9}$$

$$= K_p\, dt - t \frac{dv}{dt}\, dp; \tag{10}$$

which are the familiar and most general forms of the equations.

---

* Professor Wood employs the graphical method extensively, and his method of thus deriving the second from the first form of this equation is particularly elegant.—"Thermodynamics," § 45.

STRUCTURAL STEEL.*

By James Christie.

The lecturer was introduced by F. Lynwood Garrison, Professor of Metallurgy Economic Geology in the Institute, and spoke as follows:

Members of the Institute, Ladies and Gentlemen:

In this brief discourse, I will endeavor to describe in a popular manner a few of the properties, and an outline of the existing methods of producing the steel that is now so extensively used in structures.

We cannot pause to examine the obsolete systems which have formed successive steps in the evolution of the art. Their history is as interesting as any romance, recounting the old story of intermingled triumphs and failures; and the pages of the century are dotted with the wrecks of lives and fortunes that have been devoted to the solution of problems which have been sought by the many and solved by the few.

According to an ancient story, when Crœsus, King of Lydia, exhibited to Solon his golden treasures, Solon remarked: "If another comes who hath better iron than you, he will possess all that gold." He indicated then what is fully recognised now, that the quantity of iron produced and used is an index of a people's power and prosperity. Iron, in any form, had no widely extended application until this century, during which the statistics of increase of production tell their own story. Prior to thirty years ago, steel, even of the lowest grades, was a comparatively expensive metal; its use was confined to tools and minor purposes, for which its strength and hardness gave it preëminent advantages over wrought iron.

About thirty-five years ago, Henry Bessemer predicted that the age of steel would supersede the age of iron, as surely as iron displaced the supremacy of bronze. Bessemer is still living, and his prediction is already verified. For the leading applications in which the malleable forms of iron are used in the arts, steel has so largely displaced iron that, of the 10,000,000 tons of pig iron, which is now approximately the normal annual product of this country, about one-half is converted into steel, and the puddling furnace has ceased to be an important factor in the production of structural metal.

---

* A lecture delivered before the Franklin Institute, December 6, 1895.

It is desirable here to define what is meant by steel; for there is some vagueness and uncertainty in its accurate definition, and much of what we choose to denominate steel is known in some places as ingot iron. Indeed, it is possible to have two metals, yielding identical results by chemical analysis, one of which may be true fibrous wrought iron, and the other what we know as steel. The sole difference would be in the molecular structure, and this difference would be determined by the temperature employed in the conversion of the malleable metal from its primitive form. To understand this, it is necessary to remember that, in a general sense, the character of the metal is determined by the amount of carbon that is associated with it. To have wrought iron, the content of carbon must be very small; as the carbon content increases, the iron assumes the steely character. By increasing the proportion of carbon in the iron beyond certain limits, the metal loses its malleability and becomes cast iron. In this instance we have one of those curious anomalies frequently found in the arts, where a substance whose melting point is very high, or even when it is practically infusible, when united to some other substance, acquires by such union the property of melting at a lower temperature than that of either of its component materials. The purer iron is—that is, the freer it is from the extraneous metals or metalloids that are usually associated with it—as a general rule, the higher will its temperature be at the melting point. Therefore, in the puddling process, as the excess of silicon and carbon is reduced in the molten metal, a point is reached, at the regulated temperature of the bath, where the metal approaches to the condition of pure iron and lies in the liquid slag as a pasty, viscous mass, and in this condition is handled and finished. This process may be termed one of agglutination. On the contrary, when steel is to be produced, the temperature is kept high enough to maintain the molten condition, and it is produced from the crucible, or the converter, or the open hearth furnace, in the molten state, but is malleable after solidification; hence, steel-making may be termed a fusion process. Therefore, when we speak of structural steel, in contradistinction to structural wrought iron, it should be understood that the distinction lies in the mode of manufacture (the former being prepared by fusion, and the latter by agglutination), and not necessarily in any essential difference in the composition of the metals.

During the puddling process the iron will not agglutinate until the extraneous elements, principally carbon and silicon, are almost entirely removed. Minute proportions of injurious elements, principally phosphorus and sulphur, may remain associated with the iron to its detriment; but, broadly speaking, in wrought iron properly worked, there is little variation in its physical properties; its tensile strength will not vary very much either way from 50,000 pounds per square inch of sectional area, and it remains nearly uniform in hardness. On the contrary, by the fusion process the finished metal may retain carbon varying from nothing to 1½ per cent. or more; it may also contain, by choice or necessity, a considerable proportion of manganese or silicon. Its tensile strength may vary from below 50,000 to over 150,000 pounds per square inch of section. It may be softer than ordinary iron produced by agglutination, or it may be the hardest tool steel; yet in all its gradations, which insensibly merge together, it possesses certain characteristics which are common to all its grades, so that we cannot discern any dividing line, and assert that all metal on one side is steel, and on the other side it is not steel. It is true that a class of steel can be, and has been, largely converted from the condition of wrought iron without fusion, but that is a branch of the subject we are not considering now.

Of the numerous methods that have been proposed and tried for producing cheap steel, but two remain, and by these two methods all structural steel is now made.

One is the pneumatic process, due to Bessemer, by which a stream of air is forced through a mass of molten pig iron in a suitable vessel, and the excess of carbon and silicon in the crude metal is rapidly burnt out. At the same time, the temperature is raised so high that fluid steel remains, and is thence cast into ingots to be subsequently finished in the mill or forge.

By the other process, largely due to Martin, a mixture of pig and wrought metal, or pig and iron ore, is melted in the shallow saucer-shaped hearth of a reverberatory furnace, and subjected to an intensely hot flame. In order to obtain the intense heat necessary, the furnace is almost necessarily of the regenerative form devised by Siemens, and the resulting fluid steel is cast into ingots and handled as in the pneumatic process. The steel produced by these two distinct methods is so alike in all its characteristics that one cannot be distinguished from the other by ordinary appearance or analysis, although it is claimed that a difference can be detected by refined microscopic examination. Conversion by the Bessemer process is so rapidly completed, that it is not practicable to control the desired character of the product in the precise manner in which it is done in the open hearth furnace, from which samples of the metal can be taken and tested, and the carbon content of the molten mass raised or lowered, as desired.

By the Bessemer process the silicon and carbon of the molten pig are almost entirely burnt out, and the metal is finally recarbonised to the desired extent by the addition of sufficient spiegel or ferromanganese. By the open hearth process (at least in the acid process), reduction is stopped when the content of carbon is reduced to the proper amount for the grade of steel desired; hence, open hearth steel is preferred for purposes where a specific character is desired for the metal.

There is always found associated with iron certain elementary substances, metals or metalloids, a dozen or more in number. These combine as alloys or solutions, very much as copper, tin, zinc, etc., unite to form the bronzes. Some of the gases also are believed to be dissolved in steel, the nature and effects of which are imperfectly understood. The majority of these constituents existed in the ores as they were originally formed in Nature's crucible; a few of them are added during the process of manufacture, for specific purposes. Each of these constituents contributes to the strength and hardness of steel. This statement has been disputed and denied, but the weight of evidence tends to confirm the belief that each element adds something to strength, although they vary very much in their strengthening influence. The strengthening effect conferred by some constituents, hereafter given, has been shown by the results of extended investigations made by W. R. Webster, a member of the Institute. These results, it will be understood, are applicable only to the limited proportions of these foreign elements, usually to be found in commercial steel.

The purest iron that has been produced is a comparatively weak and soft metal. Perfectly pure iron, if it could be produced and properly forged into small bars, would have a tensile strength of less than 40,000 pounds, and probably not over 35,000 pounds, per square inch of sectional area. Of the constituent elements, some are rarely absent, others rarely present; some exercise a beneficial, others an injurious influence. The exact effect of some of the constituents has been a subject of much dispute, and authorities do not agree entirely on the subject. Some of these substances unite with iron only to a limited extent, when the metal is said to be saturated; others unite to any extent, even so great that the iron ceases to predominate, and is no longer known as iron, but takes the name of the predominating metal.

An eminent authority wrote a few years ago that he was convinced that the composition of steel is not an accurate index of its physical properties. Whilst this may be true to a limited extent, yet it is evident that the tendency in modern open hearth practice is to produce metal of more uniform composition than formerly, varying the carbon content according to the tensile strength or hardness desired, with the result that the physical properties are also more uniform than before. It is probable that each element modifies, to some extent, the influence of others, so that the interplay of the whole, due to varying proportions, becomes a matter of great complexity.

Carbon is the principal hardening and strengthening agent, and is purposely retained in combination with iron to the desired extent, according to the grade of steel required. Each 0·1 per cent. adds to the tensile strength of the metal about 8,000 pounds per square inch of cross section. Its hardening influence can readily be detected even on the very softest grades of steel. Test specimens containing 0·1 per cent. carbon, when chilled from a red heat in water of ordinary temperature, will show an elevation of the tensile strength averaging about 20 per cent. These hardened specimens are still so ductile that they can be doubled flat without fracture. With a carbon content of 0·15 per cent., the hardened specimens will occasionally crack, but usually bend nearly flat without fracture. With carbon 0·20 per cent., specimens will occasionally bend 90° or more, but usually crack. With 0·25 per cent. carbon, the steel may be expected to always crack. Above 0·40 per cent. carbon, we get steel suitable for low-grade cutting tools.

These physical properties belong to steel, in which the proportions of hardening agents, other than carbon, do not exceed the usual average in structural steel of approved quality. Manganese might be denominated a necessary evil, for it has not been demonstrated that it is directly beneficial to the steel in service; and for many purposes where the steel is necessarily subjected to destructive action, the lower the manganese the better the steel endures the punishment. But steel by the ordinary process cannot be continuously and economically made without the addition of manganese. It is supposed to eliminate or neutralise certain oxides, which are imprisoned in the fluid metal, and it is also believed to mitigate the injurious influences of the other elements that are usually present. It increases the tensile strength of the steel from 1,000 to 2,000 pounds per square inch of area, according to conditions for each 0·1 per cent. of manganese. It is ordinarily present in structural steel to the extent of 0·40 to 0·80 per cent., and is apt to cause the metal to be sensibly brittle if it much exceeds the latter proportion. It tends to reduce the magnetic property of iron, and when the alloy contains about 10 per cent. of manganese, the metal becomes practically non-magnetic. Manganese is always put into steel at the end of the heat, in both the Bessemer and open hearth processes.

The use of manganese in the manufacture of crucible steel was introduced by Heath, in England, about sixty years ago. It soon demonstrated its utility in correcting the injurious effects of foreign elements in iron, and permitted the extended use of cheaper and impure stock, especially in the lower grades of steel. Smiles says that the immediate effect was to raise the annual production of steel in Sheffield from 3,000 to 100,000 tons. Owing to a defect in Heath's patent, the process became public property without compensation to its discoverer.

Mushet, twenty years later, had a similar experience. He patented the use of manganese in the Bessemer process, making the method practicable. Mushet allowed his patent to lapse, by failing to pay the annual fee required in British patent law, and failed to obtain just pecuniary award for his important discovery, although an annuity was paid him by Bessemer, as an act of personal generosity.

Silicon may be found in minute proportions in steel as a residual constituent of the pig iron, but usually comes from the addition of ferrosilicon to the molten metal. It has the same property as aluminum, which has largely replaced it, of quieting or reducing the ebullition of the molten steel, and hence promoting soundness in ingots and castings. The percentage of this element need not exceed 0·1 per cent., but a greater amount is sometimes tolerated in steel castings, on account of the soundness it confers. Its strengthening influence is not definitely known, but it seems to exert a lower effect than manganese. Copper is frequently associated with iron in the ore, and clings tenaciously, throughout the various stages of manufacture, to the finished steel. It has always had the reputation of causing red-shortness, or brittleness at red heat. It is frequently known, however, to be present as high as 0·25 to 0·5 per cent., without causing much trouble. Some consider it especially injurious when associated with an excess of sulphur.

Sulphur is an element which it is always desirable to reduce to the lowest limit. It makes the metal short, or brittle, at red heat, and, consequently, difficult to forge without cracking. It should not exceed in proportion an upper limit of 0·1 per cent., and recent specifications frequently reduce this one-half, or more. As a hardener, sulphur raises the tensile strength of steel about 500 pounds per sectional inch for each 0·01 per cent. of the element present in the steel.

Phosphorus is the agent of evil most to be dreaded in steel. In the early days of Bessemer steel, it was found to be the principal insidious spirit of mischief that gave the metal the reputation of being capricious, treacherous, etc., and as it is widely disseminated throughout the principal deposits of iron ore, the efforts of the iron manufacturer have been ever exerted to keep the quantity within proper bounds. It is an active hardening agent, and is believed to increase tensile strength from 1,000 to 2,000 pounds per sectional inch, for each 0·01 per cent. of phosphorus in the steel.

Phosphorus has an intense affinity for iron, and as it burns to phosphoric acid when united with oxygen, it requires the presence of a highly basic flux to induce it to part company with the iron. Unfortunately, the silicious materials, which have always been used as the most cheap and useful refractories for forming the sides and bottom of furnaces, produce a slag, the principal component of which is silicic acid, and incompetent to seize the phosphorus.

It has long been known that mineral bases were abundant, and sufficiently potent for dephosphorising; but it is only in recent years that practical methods of selecting and preparing the material have been developed. Within the memory of men still living, iron was puddled in furnaces, whose sides and bottom were silicious, or acid, in the chemical sense, and therefore the slag in which the malleable metal was reduced was incompetent to seize phosphorus or sulphur. Metal fit to use could only be obtained by careful selection of suitable ores, which, in time, as consumption increased, became scarce and expensive. One of the most important improvements in the manufacture of wrought iron consisted in forming the hearth of the puddling furnace of iron plates, which were lined with iron ore; and a floor of slag, rich in oxide of iron, was prepared, on which the charge of pig iron was treated. This was a true basic process, and permitted the production of excellent iron from material that would have proved useless if made on the old sand bottoms.

The oxide of iron lining was not sufficiently refractory, nor otherwise suitable, to endure the high temperature of molten steel. Compounds of lime and magnesia, as found in the highly basic minerals, dolomite and magnesite, are now successfully used as linings for steel converters and furnaces, and to withstand the scouring action of a lime flux, which forms a basic slag, that compels the iron to part with its excess of phosphorus, and also with a part of its sulphur. Excellent basic steel is now made from material that could not be tolerated if washed by a siliceous or acid slag. The basic Bessemer process, though very little used here, is extensively used in Europe, especially in Germany, where, owing to the prevalence of phosphoretic ores, it was much needed. The basic open hearth furnace is in extensive use here, and promises to largely supersede the acid process.

The great impetus given to the production of structural steel in recent years is due, not to its superiority over good wrought iron, but to the fact that it can be produced more cheaply. The peculiar circumstances under which wrought iron is produced do not admit of the application of the perfect mechanical appliances for manipulating the metal, which are distinguishing features of modern steel works. It is usual now for structural material, such as plates, angles, beams, etc., to be finished without loss of the initial heat acquired in melting. The red-hot steel ingot passes through one, or at most two, reheating furnaces, which merely revive the fading glow on its passage through the blooming and finishing mills, and during this transit it is handled by suitable mechanism, and with so little muscular effort on the part of the workmen, that the toilsome labor that was formerly considered the inevitable lot of the iron-worker promises to be known only as a tradition.

Heavier and stronger machinery is used in the mill than was customary with iron, partly because the working heat of steel is lower than that of iron, partly because its resistance to rolling when hot is greater than that of iron, somewhere about the same ratio as the comparative strength of the cold metals, and also because the larger masses handled and the celerity of modern process demand stronger machinery. Steel castings, in the make-up of the mill appliances, have become a necessity. Steel is frequently quoted as a more homogeneous metal than wrought iron. This is only true in a limited sense. It is produced in larger single masses, free from weld or similar union, and to appearance is more uniform and works with less distress than is usual with wrought iron, but the very fact of the necessity of forging puddled iron into thin bars, and piling and reworking to make a finished product, insures a solidity that is not so certain, when the fluid mass is cast into large ingots.

As is frequently found when large masses are solidified from a liquid condition, cavities are liable to be left in the interior, during the process of crystallisation, unless the most approved methods are used. These cavities may remain a concealed source of weakness, especially in finished products of large dimensions.

Further, the extraneous elements in the steel tend to separate in the quiet fluid mass immediately before solidification, therefore the analysis frequently differs considerably at the opposite ends of an ingot. This separating tendency is intensified near the middle of the mass, where final crystallisation occurs, and there is always more or less segregation at this point, frequently resulting in a mass of steel whose composition is dangerously bad. In this sense steel cannot be denominated more homogeneous than properly worked wrought iron.

Around the center of segregation in the steel ingot, there may be a mass of metal in which the separated constituents have gathered, making it a bad, possibly a worthless, part of the metal. If the ingot is forged into a shaft, the segregated mass will probably be drawn out to a slender core along the central axis. There is, therefore, a practical advantage in boring a hole through the center of important shafts, as it probably removes a segregated core. If the ingot is rolled into a flat bar or plate, the segregated mass may spread out into a considerable area, whose location would be difficult to detect. No effective means have been adopted to insure the absence of segregation. For guns and armor, the United States Government requires sufficient of the top of the ingot to be rejected as will discard the segregated mass. It has been proposed to limit the cross sectional size of ingots; to cast as cold as practicable, in order to hasten solidification; or to submit the ingots to a clasping compression before the center is solid, and thus scatter or squeeze out the objectionable part. Doubtless, means will be adopted to prevent what is a not infrequent source of trouble.

In the workshop the treatment of steel is very similar to the old practice with iron. The more common use of the drill and rimmer, and the milling machine, is not due so much to necessity as to a growing appreciation of, and demand for, better work than was customary in former years.

Now, the laboratory and the testing room are important adjuncts of every steel works, and the chemist and the inspector are always to the front, ready to criticise or condemn.

In the forge, welding is abandoned for all work of vital importance. Work is either produced from the original solid, or else built up by riveted or screwed connections. The harder grades of steel are welded with great difficulty, and even the very softest grades are not susceptible of true welding, in the sense in which the term is applicable to fibrous wrought iron. Important forgings, whose treatment requires local heating and manipulation, are annealed by being bodily heated to a uniform temperature and uniformly cooled.

In the endeavor to obtain the most suitable metal for a purpose, some specifications confine the conditions to results of physical tests, others add chemical requirements in which a limitation is prescribed for certain combining elements, and there is a growing tendency to the latter system. It is maintained by some, as the exact effect on the steel of the union with extraneous materials is not positively known, that conformity with a high standard for physical requirements is sufficient, and that the manufacturer is only embarrassed, and the object to be gained not insured, by asking more. On the other hand, it is claimed that the ordinary physical tests do not fully disclose injurious influences, which may manifest themselves under the imperious demands of hard service. Moreover, the lower the ratio of the elements which bring a possibility of danger, the less is the risk of having these elements in injurious excess within the area of segregation.

The engineer is always compelling the manufacturer to give the best results, and doubtless has created a higher standard of excellence than would have existed under easier requirements; but frequently specifications are presented whose fulfilment is almost impracticable, and friction and delay compel an abatement of unreasonable demands.

Structural steel for buildings, bridges, etc., of excellent quality, will analyse as follows: Carbon, 0·10 to 0·25 per cent.; manganese, below 0·60 per cent.; silicon, below 0·10 per cent.; phosphorus and sulphur, each below 0·06 per cent.

Tensile tests on bars of moderate section should yield an ultimate strength varying from 55,000 to 70,000 pounds per square inch of section, according to carbon content; elastic limit not below 0·6 of the ultimate strength; the total stretch, measured in a length of 8 inches, from 20 to 30 per cent.; and a reduction of the area of the fractured section, from 40 to 55 per cent.; the ductility having the lowest values corresponding to highest tensile strength; for, as tensile strength increases, as a general rule, ductility decreases, and *vice versa.*

For rivets, it is customary to use soft, ductile steel, tensile strength below 55,000 pounds, and this is desirable if the rivets have to be set by hand; but with suitable appliances for riveting, the strongest connection will be made by using a strong metal of high quality, as heretofore defined for the body of the structure, and workmen who may be required to cut out these rivets can always bear testimony to the faithful grip they so tenaciously hold. High tension structural steel, say of 80,000 pounds, or over, in tensile strength, has decided advantages when used under compressive strains alone, but there is a natural aversion to trusting it too far, when subjected to mixed or impactive stresses, possibly for the same reason that we formerly dreaded high pressure steam or electric currents of high voltage, which are freely tolerated now.

The evil effects of phosphorus are believed to be intensified when associated with high carbon, and extreme low phosphorus basic steel is necessarily low in carbon as it leaves the furnace, as the carbon must be quite low before the phosphorus parts company with the metal to mate with the slag.

Moreover, steel, whether of high or low tensile strength, has a nearly uniform modulus of elasticity; that is, all grades extend, or compress, or deflect alike under similar loads, below the elastic limit of the material. Therefore, high tensile strength is not always available, as the engineer has to consider stiffness and rigidity as prime factors in the satisfactory use and endurance of structures. There are some reasons to believe that very pure steel is peculiarly susceptible to corrosion, and that some immunity is given by the presence of some of the usual constituents. The difference, if any, in resistance to corrosion, between ordinary commercial grades, is not very distinct, and could only be demonstrated by an extended series of experiments. The addition of a considerable proportion of nickel reduces the liability to corrosion.

Soft steel withstands high temperature in the reheating furnace better than the harder grades. Much damage may be done to a medium grade of steel by a degree of heat, especially if unduly prolonged, that would not markedly affect very soft steel.

Steel is susceptible of a profound change in its physical properties when subjected to the proper action of heat, and the method of cooling, or of so-called annealing or tempering processes.

This property is notably exemplified in the annealing of steel castings. The metal of the untreated casting has a coarse, open grain, possessing little ductility, and is comparatively brittle, although immeasurably superior to the very best cast iron. By raising the temperature of the unannealed casting to a red heat, and allowing it to cool, without any other manipulation, the coarse open grain is changed to a fine close one, resembling tool steel, as we ordinarily have it in the bar. The strength or ductility of the metal may be greatly augmented, and the texture may be made soft or hard, according to the rapidity with which the heated mass is cooled, modified, of course, by the content of carbon, which determines the ability to harden. This change is further modified by cooling in fluids of various temperatures as exemplified in the old and well-known process of oil-tempering, now practised on a large scale on ordnance and armor, and important parts of machinery and structures, where exceptional resistance is requisite. Even soft steel, as low as 0·1 per cent. carbon, will vary in tensile strength fully 5 per cent., according to the temperature at which it is finished.

An experienced authority says that every piece of steel bears in its structure a record of the last temperature to which it was subjected.

The production and manipulation of steel requires a higher degree of skill and intelligence to obtain satisfactory results than was formerly devoted to wrought iron. The condition of fusion renders the metal liable to absorb or retain injurious substances, which does not so freely occur at the lower temperature at which wrought iron is produced. A fair judgment can be expressed by an experienced eye, upon the appearance of a fractured specimen of wrought iron. No similar test can be applied to steel. First-class concerns, now, are governed by analysis of both raw and finished materials, and results checked by constant testing in the physical laboratory.

Neglect of this vigilance would result in the production of questionable metal, possibly in havoc or destruction. The faithful adherence to sound and thoroughly approved methods will result in material to which men may commit their reputations and their lives, and insure a metal which will verify the old motto, and be "true as steel."

Given a steel on which this intelligent care has been bestowed during its production and final manipulation, fashioned into a structure which embodies the carefully digested study of the designer, the product of the science and practical art of generations, and we behold a creation, the highest type of combined strength and elegance, whether it be the ocean flyer that defies the tempest, the bridge that does not quiver under the express train, or the lofty building that bears its ponderous burden, and faces the gale without distress.

THE MODERN OFFICE BUILDING.[1]

BY BARR FERREE.

A lecture delivered before the Franklin Institute, November 15, 1895.

PART I.

The largest and most costly structures now being built are the modern office buildings of America.[2] Some few monumental undertakings of foreign governments may, indeed, exceed them in price, as many a smaller building exceeds them in monumental effect; but in no other group of structures are the expenditures so large, the responsibility of architects so great, or the opportunity of profit to the designer so handsome. For the architect, the labor involved in the erection of an office building is very large. He requires a numerous corps of assistants, whose whole time for many weeks will be needed to prepare the working drawings; he will require an engineer to design the foundations and the frame of steel on which the building is to be carried, who, in his turn, will need his own assistants; he will require careful superintendents, and every step of the work will call for constant watching; he must, moreover, be familiar with many sciences and with much detail that a few years ago had no part in an architect's knowledge.[3] His building must be heated and lighted; it must be supplied with elevators and with elaborate electric and sanitary systems. Every new device must be watched and tested, in order that the latest office building may, with the utmost literalness, be "modern."

---

[1] In undertaking to treat so large a subject as the modern office building in all its phases, economic, structural and æsthetic, within the scope of a single article, it is obvious that only the most summary review can be attempted. In order that the reader, who may be desirous of pursuing the subject further, may at once place his hand upon the latest literature on the subject, references have been made, in the foot-notes, to recent articles and papers in the professional journals, in which fuller accounts of the points

But the responsibility of the architect scarcely equals that of the investor who puts his money into these great enterprises. I am speaking of office buildings of the largest size, for many smaller ones are erected, as convenient and as well equipped as the larger, perhaps, but which are not typical examples of this class of buildings. The modern office building is an exceedingly costly structure. The land on which it is erected is, as likely as not, in the center of the city's business district, where rents are high and land invaluable. The method of construction is costly; for while the steel skeleton system of construction, which is now

---

under discussion may be found. The foot-notes appended to this paper are not, therefore, offered as authorities for the statements contained in it, but as keys to more extended studies of the subjects. The references are not, in any case, to be taken in a bibliographic sense, nor is any pretence made to do more than cover the latest American literature in a most summary fashion.

[2] For a summary of the cost of some office buildings and others, see F. E. Kidder: "What Buildings Cost per Cubic Foot," *American Architect*, February 17, 1894.

[3] See an interesting paper on "The Difficulties of Modern Architecture," *Architectural Record*, Vol. 1, p. 137, by Prof. A. D. F. Hamlin.

almost universally employed in these buildings, considerably increases the interior areas, owing to the thin walls that can be built in this way, the actual expenditure, save in buildings of great height, is more than under the old system of solid walls, carrying the floor and roof loads in addition to their own weight.

An interesting case in point is the American Surety Building, in New York, which occupies a site about 85 feet square, that cost in the neighborhood of $1,500,000, or at the rate of about $8,000,000 per acre. The building itself cost at least $1,500,000 more, so that the total investment considerably exceeds $3,000,000. It has 21 stories, and is 300 feet high. Under the old system of solid walls, this structure would not have been a profitable investment, since the thickness of its walls at the ground floor would have been nearly 7 feet. As actually built, the thickness of the walls is 3 feet at the ground, and the internal area 5,000 square feet of floor space on a lot of 7250 square feet.

It is obvious that buildings so costly as this can be no ordinary structures. They represent a lavish expenditure, but a lavishness that is expended on business principles and in a business way. The office building is a commercial venture, undertaken, not with the object of beautifying the city, or of satisfying the æsthetic ideas of its owners, but as a commercial investment, in which the rents shall return a net profit that represents the income from the money it has cost. The building may be ornamental; that is to say, its ornamental aspect may be a necessary part of the scheme; but if so, it is not an æsthetic effect that is sought, but an attractive exterior and a well-planned interior, that will bring tenants and excite favorable comment from the passer-by. The artist would doubtless contend that such commercial conditions would mean the extinction of art in buildings of this description, and he would be right, in so far as many commercial buildings are totally without artistic interest, though there has been no limit to the expenditure. But though the modern office building is as yet scarcely more than in its infancy, the commercial value of a really artistic building has already been recognised by investors. And so, though the public at large—and the architects, too—scarcely understand the possibility of artistic expression in these buildings, of any two, one of good design and one of bad, the former will prove the most attractive to the better class of tenants, and, therefore, the more remunerative.

But while this is true, and the artistic side of the office building is receiving an attention not heretofore given to it, it is a purely commercial enterprise, undertaken for profit, without, save in the way that has just been pointed out, any artistic significance. And so, being a commercial building, and this being a commercial age, it is not inappropriate that our cities should be dominated by their commercial edifices, beside which the church towers are insignificant; for the office building is as typical of the life of our age as the sumptuous baths and great palaces were typical of the life of imperial Rome, or the cathedrals of the religious fervor of the Middle Ages. They have, therefore, an economic significance which no other structures of our time possess, which makes them modern in a real sense of the word.

The modern office building, as it is considered in this paper, is a purely American product. It has arisen from the concentration of the business centers of our American cities upon areas of relatively small dimensions. Its greatest development has been in Chicago, where the business center is a very small part of the city's area, and is confined within the limits bounded by Lake Michigan, the Chicago River, and the railroads centering in the city.[4] In New York, the business area is spread over a larger extent of ground, but the situation of the city on a narrow island, and the concentration of business upon the lowest extremity of this strip of land, has hastened the development of the office building in it as well as in the metropolis of the West, and for very similar reasons.

Obviously, when the pressure of population has used up the ground area, the need for accommodation becomes so great that vertical expansion is forced upon real estate owners, whether they will or no. In foreign lands such vertical expansion is hindered by vested rights, or privileges of light and air, which hem in building operations in England in a way quite unknown in America;[5] or by rigid building laws, which forbid structures of extraordinary height, or any above the average height upon streets of certain width. Building has proceeded upon freer lines in American cities, where it has seemed more suited to their development to induce a free erection of buildings than to hinder municipal growth by introducing elements of restriction. But already a reaction has set in, and many cities, Chicago among the number, have made regulations limiting the heights of buildings, and forbidding more than a certain height upon lots of a given size, or upon streets of a certain width.[6]

---

[4] "The Railway Problem of Chicago." Report of a Committee of the Western Society of Engineers. *Journal of the Association of Engineering Societies*, 11, p. 223.

How far these restrictions may be needed is problematical.[7] It has been urged that the continued erection of high buildings will make our streets veritable cañons between great walls of offices, which will not only darken them, but render the lower offices unprofitable for want of light. That a very narrow street between very high buildings is a thing to be avoided is unquestionably true; but the objections to these buildings, both on this and other grounds, have been greatly exaggerated. That they are sources of disease in preventing the free circulation of the air is as yet only a matter of opinion, while it is a fact of common observation that the wind never blows so swiftly and so strongly as around high buildings; and it is probably true that their continued multiplication will lessen the renting value of the lower floors. But commercial buildings are commercial enterprises, and the moment they become sources of danger, or any considerable part of them unrentable, at that time will come that natural check to their erection which must follow from the conditions under which they are erected.

---

[5] Banister Fletcher: "Light and Air," second edition, London, 1886.

[6] The situation in regard to limiting the height of high office buildings may be briefly summed up in this way: Every one would be glad to own a profitable high building, or any number of them. But real estate owners are divided as to their multiplication; those who have them already do not wish more, for that might mean a diminution of their profits; those who have none at all, and in this class must be included the larger number of property owners, do not want more, for that would mean a continued concentration of the business center upon one spot. The architects do not want more of them, for while they are exceedingly profitable pieces of design, the larger part of that profession have shown themselves incapable of designing them, and they wish, therefore, to get rid of the problem. The general public is opposed to them, because of the thoughtless agitation in the press and the technical journals against them, by people who do not understand their value. The newspapers of New York would loudly advocate any legislation that would render the erection of more high buildings in that city impossible, because they have high buildings of their own, and do not wish more competition than they already are subjected to. On the other hand, the high buildings have enormously increased the value of real estate in certain parts of crowded cities, and they have unquestionably given many notable structures to our cities, which, if not always joys to look at, are among the most important we possess. They have, moreover, an economic value in commercial life that has had a great influence on the methods of modern business.

[7] For a well-balanced estimate of the value of high buildings and their dangerous qualities, see D. Adler: "Tall Office Buildings, Past and Future," *Engineering Magazine*, September, 1892.

The modern office building houses an immense population. Two or three thousand people in a single one is no exaggeration. Were they built without regard to the utmost advance of sanitary and constructive science, there might be just ground for alarm at their increase. But, as a matter of fact, no buildings of our time are erected with greater care, or with a more thoughtful regard for the convenience and safety of the people who pass their working days within them. Every possible improvement is pressed into service, and the latest building, if it has been well done, is a distinct advance on its predecessor. There is still much to be accomplished; the problem of ventilation is not yet solved; perhaps the manner of heating requires further development; but these imperfections are as characteristic of lesser buildings as of the greater; they are a part of the faults of modern architecture as a whole, and are only considered in relation to the office building because of its size and importance.

It is no small achievement to erect a single structure that will contain more people than the population of a good-sized town. Countless contrivances for the safety and convenience of human life must be employed in such buildings before they can properly answer to the needs of modern commercial life. They must be well lighted, conveniently planned, amply equipped with elevators, and with the latest devices in heating, lighting, plumbing and electricity. For their proper working a vast mechanical plant is required, including boilers and steam engines, electric light apparatus, ventilating apparatus, a system of sewage disposal, and often, if the soil is full of water, an elaborate system of pumps whereby the foundations and the cellars may be kept clean and wholesome.[8] For the convenience of the tenants an army of attendants, janitors, elevator boys, firemen, engineers, electric experts and the like, is needed. There must be no break in the intricate system which keeps these buildings alive, night and day, and often without cessation the year round. Many of the factors needed to render them serviceable are invisible to the public, as well as to those who daily use them, but they form an essential part of the building, and help to make them among the most remarkable structures built by human hands, as they are among the most complex.

And not only is there an infinity of necessary devices, but the complete and modern office building includes a host of conveniences that are not, strictly speaking, a part of its architecture. It will contain, in addition to its offices, many comforts and luxuries that make it, in a sense, independent of every other building. It will have boot-blacking stands, a barber-shop, baths, restaurants, cafés, cigar-stands, news-stands, minor shops and booths, and perhaps a club, whose membership will be largely composed of the tenants. When to these are added the very varied businesses that find shelter within it, it is apparent how notable these buildings are in their contents as well as in their size and cost.

Two great factors render the modern office building capable of erection—the elevator and the skeleton system of construction. The utility of the latter in effecting an economy of renting area has already been alluded to, and the details of the system will presently be considered at length. The elevator is, of course, the chief economic device that renders the lofty buildings accessible to the public, as without it the upper floors would be inaccessible. The elevator has made the office building a commercial success, and, conversely, the demand for swift, safe and economical service has had its influence upon the development of that device, and enormously increased the elevator industry. Were any one feature to be singled out as having contributed the most to the development of the office building, that would, without question, be the elevator.

---

[8] For detailed descriptions of plumbing, heating and other mechanical devices in large office buildings in representative instances, see "American Steam and Hot Water Heating Practice," New York, 1895.

For we can erect office buildings without steel construction, as will be seen in the sequel, though not so economically. But, in a sense, we would build better; for, where five or more feet of the ground floor would be needed for a self-sustaining and supporting wall of masonry construction, there would be an end to the present custom of erecting office buildings upon narrow sites. That the practice of erecting narrow office buildings is much overdone, especially in New York, cannot be questioned, and, in time, that city will certainly show block after block of office buildings whose narrow fronts can never, from their limitations of width, have the artistic value of broad and spacious façades. Nor is the misfortune simply one of æsthetic effect. It costs more to build ten office buildings than one covering the same area, and the total operating expenses of such a series would be considerably in excess of the operating expenses of a single building. Good economy would discourage the increase of small office buildings and offer every inducement to the building of large ones. A case in point is the Monadnock Block in Chicago, in which four buildings, owned by different parties, though built in sections of two each, at different times, form one continuous interior under the same management, and practically one vast business building. A similar union of owners in building enterprises would, unquestionably, produce most satisfactory returns on the investment, which could not but be greater than the return from a number of single buildings.

In giving architectural expression to so complicated a structure as the modern office building, the architect needs to keep in view all these conditions and limitations. In a sense, he is not a free agent, in so far as he is unable to arrange his façades in accordance with the dictates of his own taste. He can waste no room in massing his front, in making a recess here, or a projection there, no matter what the artistic effect might be of doing so. On one hand stands the owner, protesting he must have every possible inch of the area for renting purposes; on the other, is the municipal building law, which forbids extension beyond the building line. All the architect can do is to keep strictly upon that line, and this, as we shall see, the skeleton system enables him to do economically and well.

Not the least of the economical advantages of the skeleton system is the speed with which it enables buildings to be erected. An office building of the largest size can now be built, with steel, in a space of time that is positively astonishing. Not only is the system a rapid one, but the lower portions of a building can be practically completed, and tenants in possession, before the upper parts are finished. As in each story, in the pure veneer type, the walls are carried on the girders at that point, it is possible to fill in any story without reference to what is above or below, and it has sometimes happened that the first floors of a high building were the last to be given their completed form. The question of speed in erection is a most important consideration in these costly structures, and this system seems to more than satisfy any requirements that may be insisted on in this particular.[9]

PART II.

The structure of a foundation[10] is determined by what it is to carry. While we build our buildings up from the foundations, their engineering begins with a consideration of the loads to which they are to be subjected—the strains and stresses. The weight of the building being calculated and fixed, the next step—though the first in actual construction—is the determination of the form of the foundations.

---

[9] Thirteen and one-half stories of the iron work of the Fisher Building, Chicago, were put in place in 14 days. This is an 18-story building, 70 x 100 feet.

[10] For general treatment of questions relating to foundations, see J. O. Baker: "A Treatise on Masonry Foundations," eighth edition, New York, 1895.

The nature of the foundation of a high building depends on the weights of the structure, the nature of the soil, the nature of the adjoining edifices and their foundations, and economy or cost. Economy, which usually comes first in mechanical operations, is the least important of the conditions, since, as the object of a foundation is to carry its building, no economical arrangement can be employed that does not recognise this fact. The adaptability of the building to its foundation need not be considered, since any sort of a steel frame can, in practice, be applied to any sort of a foundation.

The foundation will, to a great extent, depend upon the soil upon which it is built. The most desirable are those built directly upon rock; but modern engineering is independent of the nature of the soil, though whether this be rock, clay, sand or gravel will largely determine what sort of foundation is to be laid. For present purposes this aspect of the question may be neglected, and the foundations considered with reference to their structure only.

The foundations of high buildings may be divided broadly into two classes: continuous and isolated.

Continuous foundations, as their name implies, are solid, uninterrupted walls, carried wholly or in part around the building. They may rest (1) on earth or rock; (2) on piles; or (3) on beds of concrete.

A continuous foundation on earth simply requires that the soil shall be of sufficient density to support the weight that will be applied to it through the foundations. Rock requires to be cut away at the surface, and any imperfect or decaying strata got rid of.

W. M. Patton: "Practical Treatise on Foundations," New York, 1892. W. R. Hutton: "Foundations of High Buildings," *Engineering Record*, September 23, 1893, also in *American Architect*, November 18, 1893. W. H. Burr: "The Engineering of Architectural and Building Construction," *Engineering Record*, January 6, 1894, *seq*.

A continuous foundation on piles is a type not much used in the largest modern buildings. The Standard Oil Building, New York, is a good example of this kind of foundation. A similar foundation supports the Chamber of Commerce, in Boston;[11] but the piles are practically driven in groups or piers, the foundations being formed of large, rectangular sections, connected by short, narrow pieces. The interior foundations rest on true isolated piers.

Continuous foundations on beds of concrete are not frequently built. A recent example is furnished by the New York Commercial Buildings[12] (Broadway and Waverly Place), where a continuous brick wall is built directly on a bed of concrete. The foundation wall is strengthened by offsets, also resting on the concrete bed, and interrupted at alternate distances. Another method is to spread a bed of concrete upon the ground and to erect the bases of the columns upon it, as in the new Havemeyer Building;[13] or to support a bed of concrete on piles, and then place the column footings upon it, as in the American Tract Society's Building, New York.[14] This, however, is practically a pier foundation on an artificial base.

Modern building practice is chiefly concerned with isolated piers for high structures. This system was devised to distribute the heavy loads of high buildings on earth foundations over a wide area, in order to effect a uniform distribution of the weight in an economical manner. They are formed of (1) piles, (2) brick or concrete piers, (3) beams or rails, (4) caissons. Cantilever foundations have recently come into use, but as the cantilevers must be supported by one of the methods just named, that system may be neglected at present. The selection of one of these systems will depend, in great measure, upon the nature of the soil.

(1) Pile foundations for high buildings[15] offer few fea-

---

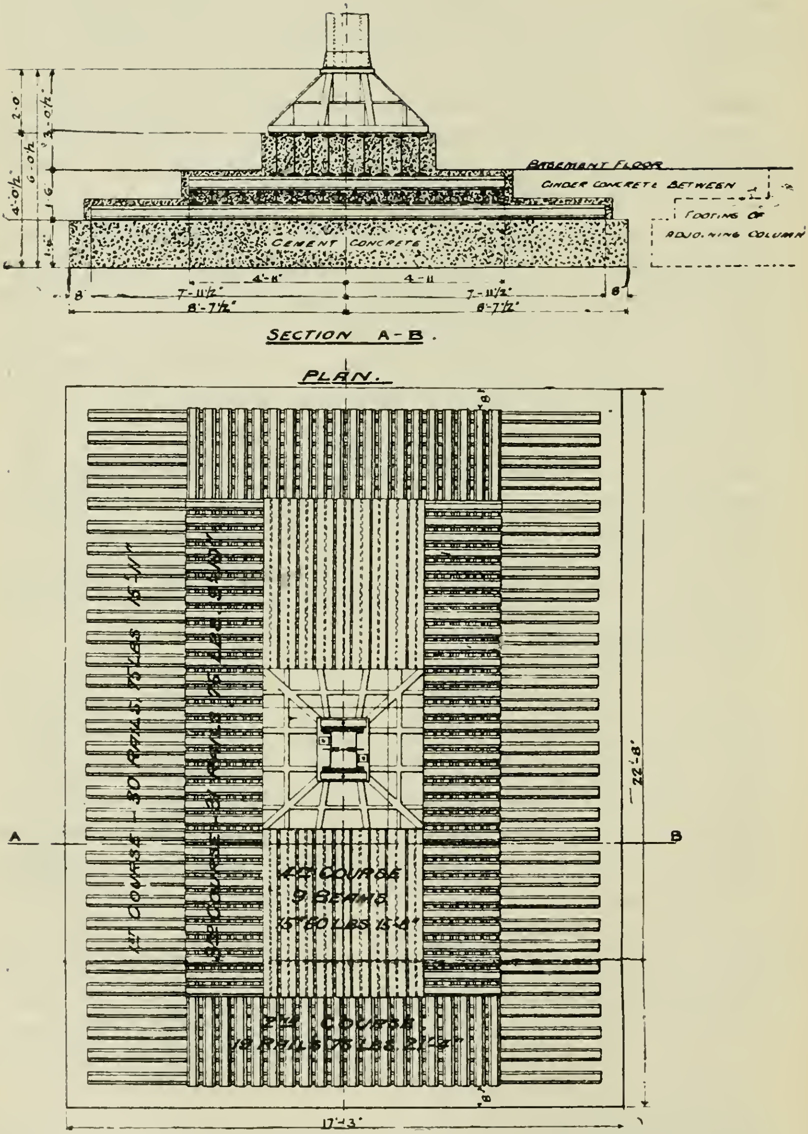
[11] *Engineering Record*, May 7, 1892; *Inland Architect*, January, 1893.

[12] *Engineering Record*, July 27, 1895.

[13] *Ibid.*, June 15, 1895.

[14] *Ibid.*, December 15, 1894.

[15] A. M. Wellington (editor): "Piles and Pile Driving," New York, 1893. Wm. Sooysmith: "Pile Foundations in Chicago," *American Architect*, August 5, 1893. "Notes on Pile Foundations in Chicago," *Engineering News*, September 21, 1893.



Section and plan of a Chicago steel rail and beam foundation, as used in "The Fair" Building, Chicago.

tures in construction that are not familiar to engineers. Their long-continued use renders them, in many respects, highly desirable foundations where the rock-bed cannot be reached, and where there is a hard stratum to which they can be driven. Piles were almost universally employed prior to the introduction of the isolated pier system, but were somewhat neglected after steel rails began to be used. Recently their employment has been revived to a considerable extent, and in Chicago they have, in some instances, taken the place of the distinctive rail foundations. In 1889 piles were employed for the Wisconsin Central Depot, and, subsequently, in the Schiller Theatre, the Newberry Library, and the Stock Exchange in Chicago. Special pains were taken with the foundations of the Newberry Library, which were subjected to an elaborate series of tests.[16] Good practice requires that the piles should be driven to rock or to hard-pan. A proper penetration of a hard stratum is often sufficient, if the rock is too low down, for the piles may be held in place by frictional resistance without actually resting on a solid substance. The piles should be cut off below water-level at a sufficient depth to permit any timber grillage erected on them to be permanently under water.

(2) Brick or concrete piers are seldom employed in the best and latest construction, on account of their poor economy of space. The Drexel Building, Philadelphia,[17] is supported by foundation piers of hard brick in concrete, connected by inverted arches whose heads are embedded in the concrete on which the footings rest. Some of the large piers of this foundation are of granite.

(3) The raft or rail foundations[18] were devised to overcome the difficulty of supplying an adequate support to the great office buildings on the compressible soil, largely of clay, of Chicago. Since their introduction they have been found to have so many advantages that they have been used

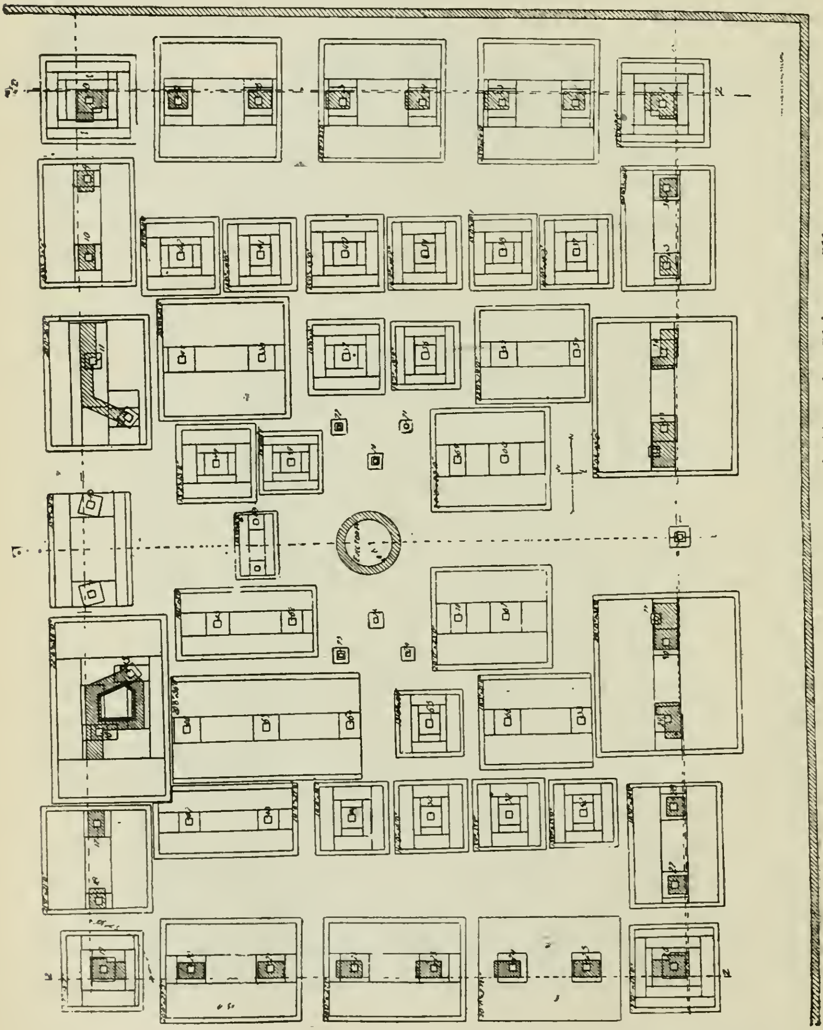
---

[16] *Engineering News*, July 6, 1893.

[17] *Engineering Record*, May 4, 1889, *seq.*

[18] C. T. Purdy: "Steel Foundations," *Engineering News*, August 8, 1891. W. L. B Jenney: "Chicago Construction," *Engineering Record*, November 14, 1891; also in *Inland Architect*, November, 1891.

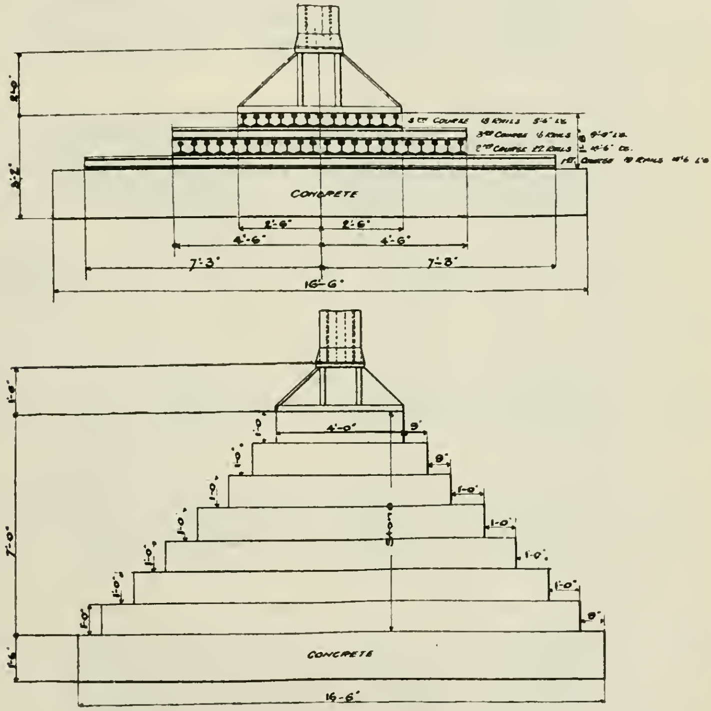
elsewhere. At first they consisted of old rails, then of I-beams for the upper course or courses; at present, I-beams especially manufactured for this purpose are employed.



Foundation piers of the Masonic Temple, Chicago, Ill.

This type of foundation is relatively simple; a layer of concrete supports the layers of I-beams, all encased in concrete to protect the steel, and supporting a casting to which is applied the base of the column of the frame. It has many advantages.

It causes a great saving of space. A steel foundation, whose height between its bed of concrete and the bottom of the casting on which the column rests is 1 foot 8 inches, will be equivalent to a masonry foundation 7 feet high, when the latter is stepped out to transmit the load over the same area. This saving of space amounts to the height of a basement, which is an item of more moment in Chicago than in New York, because the soil of Chicago does not offer opportunity for basements and sub-basements with ordinary construction. At the same time, the steel foundation is much lighter in weight than the corresponding foundation of stone, and this permits the addition of an extra story to the building without adding to the load on the soil. Steel foundations are more costly in themselves



Comparative section of steel and stone foundation.

than stone ones, but their great economy in space, in weight, and in the time necessary for their erection, more than compensates for their increased price. To the other advantages must be added the final one that masonry foundations are often unfortunate for sidewalls, because they cannot be properly stepped out on both sides without encroaching on the adjacent lot.

Examples.[19]—Beam and rail footings, Chicago: The Fair, Manhattan, Isabella, The Rookery, Monadnock, Woman's Temple, Masonic Temple,[20] Marshall Field, Rand-McNally,[21] Reliance, Teutonic.

Beam foundations, Chicago: Leiter, Y. M. C. A., New York Life, Fort Dearborn,[22] Tacoma, Pontiac, Caxton, Venetian, New Monadnock, Marquette,[22] Steinway Hall,[22] Atwood[22] (with cantilevers), Old Colony[23] (with cantilevers). New York: New Havemeyer,[24] Wilks.[25] Pittsburg: Carnegie.[26]

In the New Havemeyer, Wilks and Carnegie Buildings, the concrete covers nearly the whole area of the foundations, and on this the I-beams of the footings are placed. In Chicago the concrete is spread in beds under the footings, practically covering the area, but arranged in definite shapes and sizes.

(4) While the raft system has been found practically sufficient to carry the heaviest buildings of Chicago, it has been thought desirable, by some engineers and architects, to carry the foundations down to the rock level. For this purpose, caissons, sunk by pneumatic or hydraulic processes, have come into use. Local circumstances will determine the process of sinking them. As foundations, they consist of circular, rectangular, or variously shaped cylinders or enclosures of sheet metal, filled with concrete and brick.

---

[19] No attempt has been made in this, or similar lists, to compile a full list of examples; only a few well-known buildings are named in each class.

[20] *Engineering Record*, January 21, 1893, *seq.*

[21] *Ibid.*, December 12, 1891, *seq.*

[22] *Engineering News*, October 17, 1895.

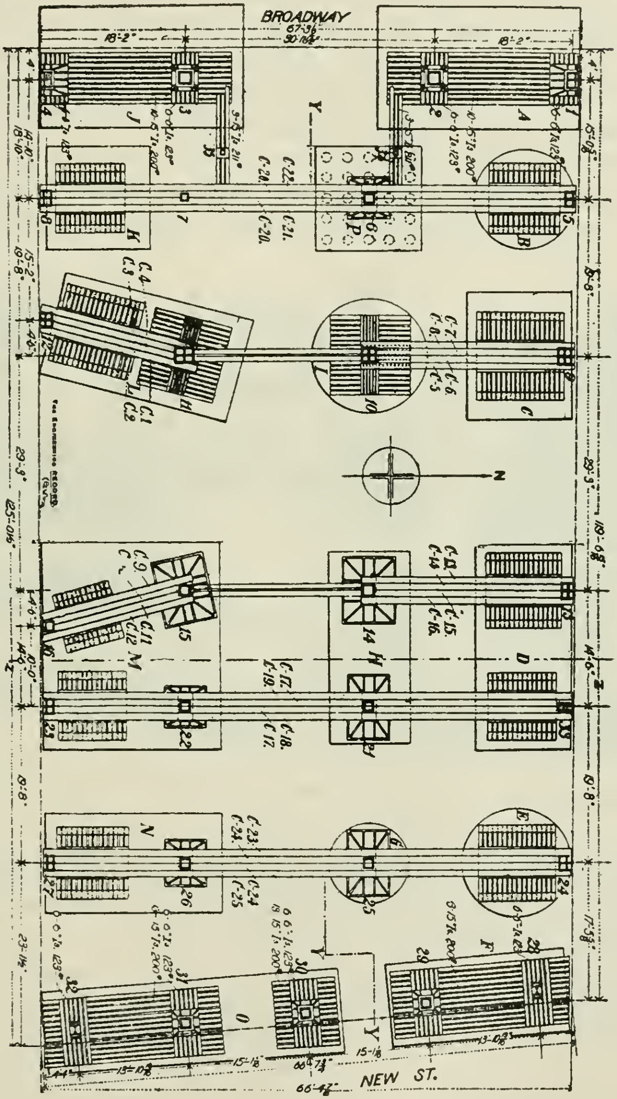
[23] *Ibid.*, December 21, 1893.

[24] *Engineering Record*, June 15, 1895.

[25] *Ibid.*, June 1, 1895.

[26] *Engineering News*, January 11, 1894.

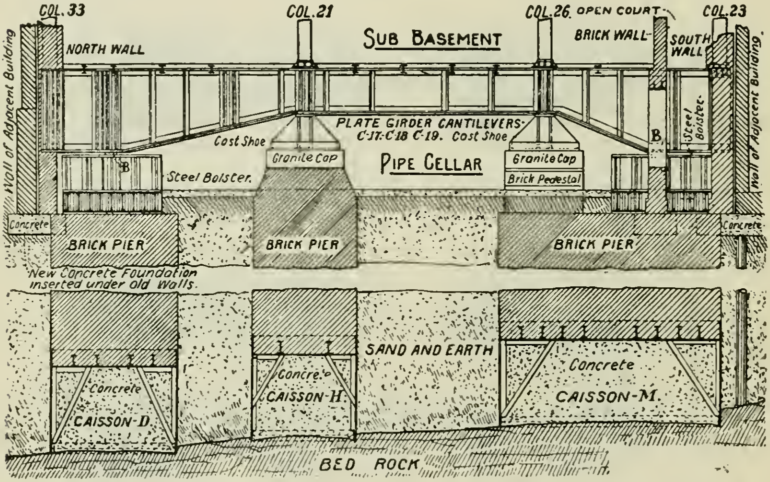
These are covered with a proper cap, to which is applied the casting for the base of the columns. They are, in fact, simple columns or piers of masonry, which carry the weight of the building to the rock below. Examples of this type



Plan of foundation Manhattan Life Insurance Building, New York.

of foundation are found in the Manhattan,[27] the American Surety[28] and Johnston[29] Buildings in New York, and in the new addition to the Standard Oil Building in the same city.

Where it is possible to build directly upon the building line, and the shape and size of the site permit the structure to be carried directly upon foundations so placed, the engineer has no other course to pursue than to apply his frame directly to them. But it is not always possible to get the foundations directly upon the building line; other structures may be so closely built upon it that their safety would be imperiled by sinking foundations for a new edifice; or other local circumstances may call for special treatment.



Section through foundations, Manhattan Life Insurance Building, New York.

An obvious device for transferring the load from an impossible position to one where it may be safely located, is the cantilever. In New York, it has been employed in the new addition to the Western Union Building, to transfer a load from one corner to a more secure footing. In Chicago, it has been used in the Manhattan and the Rand-McNally[30] Buildings, because heavy machinery in the basements of the adjoining structures could not be moved to permit the introduction of new party-footings. More recent examples in the same city are supplied by the Atwood[31] and the Old Colony Buildings.[32] In the former the north and west walls are carried on cantilevers; in the latter, the south wall. In New York a part of one wall of the American Tract Society's Building is carried on cantilevers.[33]

---

[27] *Engineering News*, December 7, 1893; *Engineering Record*, January 20, 1894.

[28] *Engineering Record*, July 14, 1894; June 6, 1895.

[29] *Ibid.*, July 13, 1895.

In all these instances only a portion of the building, as a corner or a single wall, is carried on the cantilevers. A much bolder innovation was to carry the weight of an entire building on them, as in the Manhattan Building in New York.[34] This structure has a frontage on Broadway of 67 feet, and is 119 feet deep to New Street on the north, and 125 feet on the south. Its height above Broadway is 242 feet, with a tower and dome, that make the total height, from curb to foot of flagstaff on the dome, 348 feet. A series of rectangular and circular caissons was sunk, some carrying two columns, some one. A cross section of the foundation shows four supports for the cantilever girders, and on these are applied the columns of the superstructure.

The problems that come before the constructive engineer in the high buildings are so varied and complicated that even the very considerable number of types of foundations already considered do not fulfil every possible requirement. But those just noted are the usual types of office building foundations, and one or the other of them may be found in almost every great building. Special circumstances, however, call for special treatment, and some interesting examples of what may be termed special foundations may be briefly noted.

Cable Building, New York.[35]—To obviate the intense vibrations of the cable machinery, a system of double foundations was devised. The inner columns of the superstructure rest on steel foundations of the usual type, applied to concrete enclosed within steel cylinders 6 feet deep and from 4 to 12 feet in diameter. A heavy layer of concrete covers the ground around these cylinders, and serves as a foundation for the machinery. The outer columns were built within the enclosing walls, on grillages formed of a single layer of steel beams, 24 feet above the beginning of the walls.

---

[30] *Engineering Record*, December 12, 1891, *seq.*

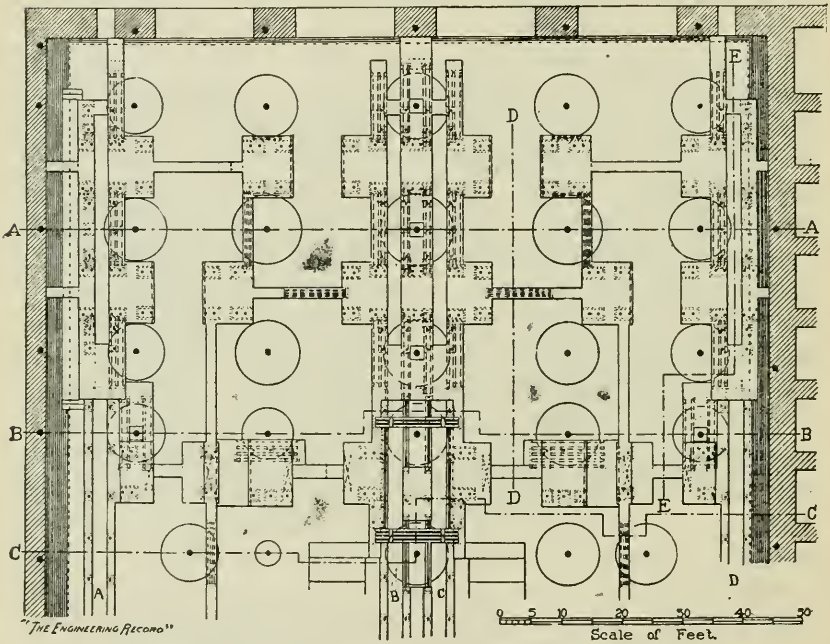
[31] *Engineering News*, October 17, 1895.

[32] *Ibid.*, December 21, 1894.

[33] *Engineering Record*, December 15, 1894.

[34] *Ibid*, January 20, 1894.

[35] *Engineering News*, October 5, 1893; *Engineering Record*, September 3, 1892.



Portion of foundation plan of Cable Building, New York.

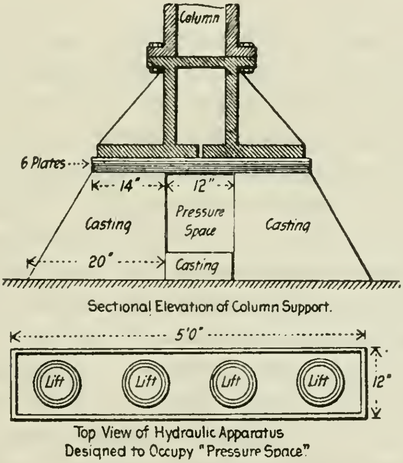
Marquette Building, Chicago.[36]—The foundations of the west wall of this building were designed to carry an additional structure not yet built. The present load is, therefore, unequal and different from the final load. A special device was introduced to meet this condition in the column footing applied to the usual I-beam and concrete base, consisting of a cast steel shoe resting on six plates, which, in turn, rest on two large iron castings, with a space between, in which is an hydraulic apparatus with four lifts. Should the wall give evidence of settling, the pressure can be applied and the thin plates between the castings removed, or additional ones inserted, as may be required.

---

[36] *Engineering News*, October 17, 1895.

New Havemeyer Building, New York[37] (on site of old Herald Building).—A similar device of hydraulic lifts will be applied to this building, to provide for a possible heavy adjoining building in the future.

Fisher Building, Chicago.[38]—In this structure an attempt was made to provide a device which would squeeze the water out of the ground before the building was placed on it. In this way it was hoped to form a solid base which would overcome the settlement which follows from the squeezing of the water by the weight of a heavy building, and at the same time obtain a resisting strata for the piles, sufficiently firm to render driving to hard pan unnecessary. Piles 25 to 27 feet in length were driven close together under each column. About 6 inches of concrete was packed close below the tops of the piles, and 18 inches placed on


Column
6 Plates
14"
12"
Pressure Space
Casting
Casting
20"
Casting
Sectional Elevation of Column Support.
5'0"
Lift
Lift
Lift
Lift
12"
Top View of Hydraulic Apparatus Designed to Occupy "Pressure Space."

Adjustable column support, Marquette Building, Chicago.

---

[37] *Engineering Record*, June 15, 1895.

[38] *Engineering News*, October 17, 1895; *Engineering Record*, October 19, 1895.

top. On this was built a steel beam and concrete foundation, with a shoe of the usual form. This system has been employed by the same architects and engineers in the Mabley Building, in Detroit.

Old Colony Building, Chicago.[39]—This building offers a good type of a combination of a direct and cantilever foundation. The north wall is carried on cantilevers; the others are supported by columns that rest directly on concrete and beam foundations of the usual type. The distribution of the load was such that six columns were included on the single large concrete base supporting the footings of the cantilevers.

The typical modern office building consists of a cage of steel enclosed within stone and terra-cotta or brick walls, the weights, strains and pressures being carried wholly on the metal frame, and by it transmitted to the foundations.[40] This system is well defined in the Chicago building law:

"The term 'skeleton construction' shall apply to all buildings wherein all external and internal loads and strains are transmitted from the top of the building to the foundations by a skeleton or framework of metal. In such framework the beams and girders shall be riveted to each other at their respective junction points. If pillars made of rolled iron or steel are used, their different parts shall be riveted to each other, and the beams and girders resting upon them shall have riveted connections to unite them with the pillars. * * * If buildings are made fireproof entirely, and have skeleton construction so designed that their enclosing walls do not carry the weight of floors or roof, then their walls may be reduced in thickness one-third from the thicknesses hereinafter provided for walls of buildings of the different classes, excepting only that no wall shall be less than 12 inches in thickness; and provided also, that wherever the weight of such walls rests upon beams or pillars, such beams or pillars must be strong enough in each story to carry the weight of the wall resting upon them without reliance upon the walls below them. But if walls of hollow tiles are used as filling between the members of the skeleton construction, they shall be of the full thickness specified for non-skeleton buildings."

---

[39] *Engineering News*, December 21, 1893.

[40] W. H. Birkmire: "Skeleton Construction in Buildings," second edition. New York, 1894. J. K. Freitag: "Architectural Engineering," New York, 1895. C. T. Purdy: "The Steel Skeleton Type of High Buildings," *Engineering News*, December 5th, *seq.* C. T. Purdy: "The Use of Steel in Large Buildings," *Journal of the Association of Engineering Societies*, 14, p. 182, reprinted in *Engineering Record*, February 16, 1895, *seq.* C. T. Purdy: "Steel and Iron Construction in Buildings," *Inland Architect*, June, 1892. "High Buildings of Steel Construction," *Engineering News* December 27, 1894. P. B. Wight: "Recent Fire-Proof Building in Chicago," *Inland Architect*, February, 1885, March–June, 1892. D. Adler: "Tall Buildings," *Inland Architect*, June, 1891. C. H. Blackall: "Specification for Structural Steel Work," *American Architect* December 22, 1894. "New Office Buildings in Chicago," *Engineering News*, February 16, 1893. "Recent Chicago Tall Buildings," *ibid.*, October 17,

All office buildings are not of this type, and practice varies among engineers to a much greater extent than is generally supposed. Some very large office buildings have been built of solid walls throughout; in others some or all of the walls are self-sustaining; in others, again, such self-sustaining walls are strengthened by steel girders, or the lower part of the wall will be self-sustaining and the upper parts be carried on girders, thus reducing the space and weight of the lower walls; in others, finally, and this is the typical skeleton construction, the walls are carried on the frame at each story.

Solid walls, without steel columns.—Monadnock, old part;

1895. W. J. Fryer: "Skeleton Construction," *Architectural Record*, 1, 228. L. De C. Berg: "Iron Construction in New York City," *ibid.*, 1, 448. G. Hill: "Some Practical Limiting Conditions in the Design of the Modern Office Building," *ibid.*, 2, 445.

For detailed studies of the construction of notable office buildings consult: "Drexel Building, Philadelphia," *Engineering Record*, May 4, 1889, *seq.* "World Building, New York," *ibid.*, November 1, 1890, *seq.* "Rand-McNally Building, Chicago," *ibid.*, December 12, 1891, *seq.* "Boston Chamber of Commerce," *ibid.*, May 7, 1892, *seq.* "Masonic Temple, Chicago," *ibid.*, January 21, 1893, *seq.* "Old Colony Building, Chicago," *Engineering News*, December 21, 1893. "Manhattan Life Insurance Building, New York," *ibid.*, December 7, 1893. *Engineering Record*, January 20, 1894, *seq.* "New Havemeyer Building, New York," *Engineering Record*, June 15, 1894. "American Tract Society's Building, New York," *ibid.*, December 15, 1894. "Wilks Building, New York," *ibid.*, June 1, 1895.

Auditorium; The Rookery; Woman's Temple; Marshall Field; Owings Building—all in Chicago.

Mixed walls, part solid, part veneer.—The new Monadnock in Chicago consists of two parts, exactly alike externally. One, the Katahdin Building, has its exterior walls supported by masonry piers, 7 feet thick at the level of the first floor; the other part, the Wachusetts Building, is of the pure skeleton type.[41]

The Mail and Express Building, New York, is an L-shaped structure, with an exceedingly narrow arm reaching out to Broadway. All the walls are self-sustaining, including the fronts on Broadway and Fulton Street, except the side walls of the narrow arm, whose steel construction was necessitated by the fact that solid walls would have left no practical renting area between them.

In the Manhattan Building, New York, the walls are wholly, or in part, of the skeleton type, except the Broadway front. "The first story on Broadway, up to the springing of the arches of the windows, is of granite, the full thickness of the wall. Thence up to the first story cornice the thickness of the stone is equal to the reveals of the windows directly over the openings, the piers running up solid to the cornice, and being backed up over the windows with brickwork to the full thickness. Each stone is securely anchored and tied to the brickwork, and a thorough and efficient bond is maintained throughout the entire brickwork once in every five courses, and every course of brick is solidly filled in with cement. The intervening walls between piers on the north and south lines are supported on arches extending from pier to pier."[42]

Self-sustaining walls, carrying themselves only, as in the Auditorium Annex and the Masonic Temple in Chicago. In the last example it was found that the maximum pressure on brickwork, 12 tons per square foot, would be exceeded at the fifth story. Brackets were, therefore, attached to the metal columns placed within the masonry piers, at the fifth and sixteenth floors, to carry the masonry work. The walls were thus only self-sustaining to the brackets of the fifth floor.

---

[41] *Engineering News*, February 2, 1893.

[42] *Engineering Record*, August 18, 1894.

The World Building, New York, offers a type peculiar to itself, which may be classified under this head. It consists of two parts, a shell and an interior. The walls are entirely free from the steel columns which carry the weights of the floors, and which stand free from the self-sustaining enclosing walls. In the Cortlandt Street Havemeyer Building, New York, a later structure by the same architect, the walls are immensely thick piers of masonry containing a metal column placed near the inner surface, that carries the floor load.[43]

Veneer walls, in which all the weights are carried on metal columns. This is the typical Chicago system of high building construction, and the list of examples includes a large number of the more important office buildings of that city.[44] Among these may be named the Home Insurance Building, Manhattan, The Fair, Leiter, Y. M. C. A., Isabella, New York Life, Fort Dearborn, Tacoma, Pontiac, Caxton, Venetian, Old Colony, Champlain, Marquette, Stock Exchange, Great Northern Hotel, Ashland, Rand-McNally, Reliance, Title and Trust, Boyce, Hartford, Unity, Security, Columbus Memorial, Teutonic.

[*To be concluded.*]

---

[43] *Engineering Record*, November 1, 1890, *seq.*

[44] It should be remarked that very considerable differences in steel construction exist between the practice of New York and Chicago engineers. In the latter city, the unreliability of the soil and the imperative necessity of loading it as lightly as possible, have made its engineers eager to avail themselves of every device which would lighten their loads. New York, on the other hand, has a perfectly stable soil that can be loaded to any extent, and its engineers have, therefore, been much less chary of the use of metal. In Chicago, the natural tendency is to remove every pound of metal that can be spared ; in New York, a surplus of metal is often employed. Chicago, therefore, possesses the most typical examples of skeleton and veneered construction.

NOTES AND COMMENTS.*

THE CHICAGO DRAINAGE CANAL.

The report of the Board of Engineers detailed by the Secretary of War to report upon the probable effect and operation of the Chicago Drainage Canal upon the lake and harbor levels, and upon the navigation of the great lakes and their connecting waterways, has been made public. There is nothing to show, the report says, that the consent of Congress has been asked for this enterprise, and it is certain that it has not been treated as an interstate or international affair. With this established fact, it is impossible to think that supervision of the United States will not extend to the canal in due time. This will become necessary as soon as it becomes a part of the system of navigable waterways. If the new outlet reduces the levels of Lakes Michigan and Huron about 6 inches, that effect will be produced in about two years. This is, therefore, not a question of many years, as some suppose. The board feels very sure, therefore, that: (1) the drainage canal is not solely a State affair, but a national one; (2) the tapping of the lakes must affect their levels. If the level of the lakes should be reduced, vessels would have to load accordingly. The trustees of the drainage company now contemplate the abstraction of only 300,000 cubic feet per minute, but after the canal is opened it is assumed that 600,000 cubic feet will be drawn from Lake Michigan. This would lower the level of all the lakes of the system except that of Lake Superior, and reduce the navigable capacities of all harbors and shallows throughout the system. Under the laws of the United States these changes in capacity cannot be made without Federal authority, and, to enable the executive officers of the United States to act advisedly in the matter, it is necessary, in the opinion of the Board, not only that measurements be taken, but also that the money cost of restoring the navigable depths in channels and harbors be carefully estimated. The navigable capacity of all harbors and channels on the Great Lakes below St. Mary's Falls would be injuriously affected by the proposed canal, and the navigability of the inner harbor of Chicago would be made difficult by the introduction of a current therein.—*Scientific American.*

UNSOLVED PROBLEMS IN THE MANUFACTURE OF LIGHT.

Prof. John Cox, in a recent lecture on the above-named theme, before the Royal Society of Canada, presented, in a very striking way, the enormous percentage of loss of energy in all attempts heretofore made to manufacture light through the agency of the steam engine.

To begin with, he points out that in practice not more than from 7 to 16 per cent. of the energy of the fuel used can be realised through the engine, and theoretical considerations establish a limit at about 30 per cent., beyond which it would seem to be hopeless to expect to pass in any form of heat engine. This he terms one of the unsolved problems.

---

* From the Secretary's monthly reports.

It is, however, not unsolvable, if we can devise some means of extracting the energy of coal otherwise than by heat—say, in some such manner as that used in burning zinc in a voltaic battery. That this is not beyond the scope of our present scientific knowledge, the recent experiments of Borchers and others bear strong evidence.

In the second stage of the operation of producing the electric light, the dynamo is already so nearly perfect that hardly any heat is lost in its conversion into current.

The third stage brings us to the lamp, with some 7 per cent. of the original energy still available. The only means thus far available for producing luminous energy is to heat the molecules of some substance, and in this operation we are compelled to waste the greater portion of our available energy in producing heat before we obtain the light rays.

" Here, then, is the second unsolved problem, since even in the incandescent lamp and the arc lamp not more than from 3 to 5 per cent. of the energy supplied is converted into light. Thus, of the original store in the coal less than three parts in a thousand ultimately become useful. In the last six years, however, some hint of means to overcome the difficulty has been obtained from the proof by Maxwell and Hertz that light is only an electric radiation. Could we produce electric oscillations of a sufficient rapidity, we might discard the molecules of matter and directly manufacture light without their intervention. To do this we must be able to produce oscillations at the rate of 400,000,000,000 per second. Tesla has produced them in thousands and millions per second, and Crookes has shown how, by means of high vacua, to raise many bodies to brilliant fluorescence at a small expense of energy. * * * These are hints toward a solution of the problem, but give no solution as yet. Prof. Langley states that the Cuban firefly spends the whole of its energy upon the visual rays without wasting any upon heat, and is some four hundred times more efficient as a light producer than the electric arc, and even ten times more efficient than the sun in this respect. Thus, while at present we have no solution of these important problems, we have reason to hope that in the not distant future one may be obtained, and the human inventor may not be put to shame by his humble insect rival."

ACTION OF THE ELECTRIC CURRENT ON FUSED SULPHIDES.

The *Engineering and Mining Journal* gives the following abstract of a paper read by M. Garnier, at one of the recent meetings of the French Academy :

After having determined that carbon, heated to redness under the influence of an electric current of feeble voltage, is transported from the positive to the negative electrode, which fact permitted me to indicate a new method of iron cementation, I thought that this action of an electric current ought not to be limited to carbon. To determine this fact, I made experiments in the laboratories of M. Hillairet. I employed a tube of refractory material placed horizontally in a reverberatory furnace, and receiving the matter to be electrolysed between the two electrodes in the heated part of the tube. The current was furnished by a Gramme machine. I operated it first on a raw nickel matte from Sudbury, Ontario. I placed a certain quantity of it in the middle of the tube between the two carbons. The spaces between the carbon rods and the walls of the tube were filled with refractory earth mixed with charcoal, to guard against the intrusion of oxygen, but not the exit of gas under feeble pressure, which is formed during the electrolysis, and which can thus escape by the cracks which the heating produces in the clay mass. The matte being melted, I passed a current of ten volts and twenty-three ampères; the current only showed feeble oscillations according to the voltmeters, proving that there was a great regularity in the conductibility of the molten mass. Moreover, the voltage was gradually lowered, although the temperature of the reverberatory furnace was almost constant, which went to prove that the nature of the mixture was changed. After an hour of heating, slow cooling and stoppage of the current, I opened the tube. The positive carbon rod was worn to a feather edge at its upper end, while the negative rod remained intact. Of the matte an analysis was made of those parts which were solidified at the point of contact of the two electrodes. Only the insoluble parts which existed in fragments of the walls of the tube strongly attached to the matte, even after cooling, were eliminated from the samples. Of the analyses given below, No. 1 is of the matte taken; Nos. 2 and 3 are respectively those of the material in contact with the anode and of the cathode after the electrolysis, and No. 4 shows an average of Nos. 2 and 3:

	(1)	(2)	(3)	(4)
S%	21·10	16·60	4·70	10·65
Fe%	33·30	35·40	49 10	42·30
Ni%	16·30	5·13	19·10	12·14
Cu%	29·00	39·90	26·13	33·02
	99·70	99·20	99·03	98·11

These analyses show that fifty per cent. of the sulphur is eliminated, which sulphur keeps with the copper, especially near the anode; that the iron remains near the cathode, where it seems to accumulate according to the average analysis, No. 4; that the nickel regularly increases in quantity from the anode to the cathode, and the copper diminishes in a regular arithmetical progression from the anode to the cathode. I think that one may conclude from the results of the above experiment that (1) the sulphur combined with the metals in the molten state, in the absence of air when traversed by an electric current (the electrodes, at least the anode, being of carbon), is gradually eliminated in the form of sulphide of carbon; (2) in a mixture of molten metallic sulphides, in the absence of air traversed by an electric current, the electric conductivity of the mixture remains homogeneous at every moment, increasing little by little on account of the gradual elimination of sulphur; the metals and the remaining sulphur arrange themselves in such a way that each elementary section of the bath taken perpendicularly to the direction of the current, has the same electrical conductivity; thus the copper, a better conductor than iron or nickel, keeps the greatest portion of the sulphur, so that its conductivity may be reduced in the desired proportion.

It is possible, I think, from the above experiments, to explain certain observed phenomena; for example, the mode of distribution of the metals free from, or combined with, sulphur in veins.

UNDER-SURFACE ELECTRIC RAILWAYS.

It has been announced, apparently from authoritative sources, that the results gained by the operation of the Lenox Avenue road, in New York, which has been operated for several months on what is known as the Buda-Pesth underground conduit system, have given great satisfaction. The saving exhibited, it is reported, is 4 cents per car-mile over cable service, and 8 cents per car-mile over horses. In consequence, the Metropolitan Street Railway Company, of New York, under whose direction the above-named experiment was made, has given out the statement that all of the cable and horse railway lines controlled by that company will be equipped for operation by electric power on the under-surface system.

The Electrical World, in discussing the subject editorially, regards the foregoing announcement as highly important, believing that it "may be considered to definitely establish the status of underground conduit working, which will, with scarcely a doubt, soon supersede cable traction throughout the United States, and also lead to a considerable extension of electric traction in our larger cities."

Referring to the Lenox Avenue experiment, it appears that the line has not been subjected to the test of winter weather; the fact, however, that no special trouble from moisture has been experienced at Buda-Pesth, during the five years it has been in operation, is reported to be regarded by the officials of the New York Company as sufficient assurance that no real difficulty will be experienced there from that cause.

The World's editor, indeed, goes so far as to express the belief that the matter is already settled, as witness the following extracts from his comments:

"The question as to trouble from moisture, formerly thought to be inseparable from an open conduit system, has been the crucial one, and is now happily settled. The simplest system of underground conduit electric traction having been demonstrated to be entirely satisfactory, one cannot help but reflect upon the immense waste of ingenuity, and the great expenditure of money and time, on complicated systems devised to obviate difficulties that never had any practical existence."

DEFECTS OF "FIREPROOF" BUILDINGS.

Commenting on the recent disastrous fire at Broadway and Bleecker Street, in New York City, and which involved the destruction of the Manhattan Savings Institution—a modern eight-story iron structure, consisting of an iron frame or skeleton, filled in with masonry—the *Scientific American* points out, and illustrates by sketches, several grave defects of construction, to which the vulnerability of this building, and presumably of many others may be largely ascribed. One of these is ascribed to the absence of adequate protection of the I-beams of the several floors by fireproof blocks or slabs—which, in this particular case, and doubtless in many others, are carried approximately flush with the base of the I-beams, but do not, as they should, project under and cover them. The lower flange of these beams, it will therefore be seen, has no other protection than that afforded by the ceiling plaster; and the lower half of the main girders has no protection against the heat of a fire. In this particular case, the radical fault of this construction was shown by the fact that, when the fierce flames struck the lower flange of these girders, they stretched and sagged down with their load of I-beams, pulling with them the brick piers upon which their outer ends were borne.

The cheap character of the brick protection also is referred to as another serious fault which contributed to the disaster. In this case, the solid brick arch, instead of springing from the flanges of the I-beams, and being covered to the level of the flooring with sand or ashes, consisted simply of a single layer of thin slabs of brick, with an open air space of 12 inches between this and the wood flooring above.

The conditions necessary to be realised in the ideal fireproof building, according to the writer of the foregoing criticism, are stated in the following terms:

"(1) It should be proof against attack from without.

"(2) The skeleton frame, consisting of steel columns and horizontal girders, should be inclosed in some thoroughly fireproof material.

"(3) It should be able to localise a fire, and confine it to the particular floor upon which it originates.

"In the case of the majority of buildings there is evidence of an attempt at fulfilling the third condition, a partial attempt at the second, and none whatever at the first.

"The first condition can only be met by reducing the window space; building the walls with a facing of the very best firebrick, and furnishing every window with a plate or roller shutter of steel.

"The second condition can be reached by walling in every column and every main girder with high-class firebrick, leaving between the brick and the metal a space that shall be filled in with a preparation of asbestos, similar to that now used on steam piping, or with some similar non-conducting material.

"The third condition can be attained by building firebrick floors with cement finish, abolishing all woodwork, and using metal window casings and sashes, providing each elevator landing with plate steel doors, and, lastly, placing on each floor a powerful water supply. Such a building would be costly, but it would be fireproof." W.

TECHNICAL NOTES.

Among the technical novelties, recently exhibited at the stated meeting, were specimens of *Falconnier's blown glass bricks*. These have been in use in France and Germany for more than five years, and should not be confounded with the solid blocks of glass formerly used with little success for similar purposes.

Falconnier's blown glass bricks are very light and very strong. They are, in fact, hollow chambers, so shaped as to facilitate their being put together like other building blocks, and are laid so as to present an ornamental appearance. Made in this fashion, the bricks fill successfully the part of double windows with an air chamber incased in a double glass wall, and they are consequently an efficient preservative against cold as well as against heat, and good insulators of dampness and noise. These bricks are hermetically sealed while yet hot, thereby preventing foreign substances or dust from soiling the interior, and they are then annealed to increase their powers of resistance.

The laying of these bricks is plain bricklayers' work, the vaults being constructed over a center of wood, heavy lime mortar, or light cement mixed with fine sand, being used after the whole width of the joint around the brick has been covered with a layer of sizing of a light tint that can be varied according to taste, so as to obtain nice effects of changing colors if desired.

These glass bricks, it is said, are used with good results in the construction of greenhouses and conservatories, as they retain the stored heat for a long time ; consequently, a considerable economy of fuel is realised, and also the loss of plants by any sudden or great changes of temperature is averted. They withstand hail and shocks. Sunstrokes which burn delicate plants need not be feared, the surfaces of the bricks being combined so as to diffuse the rays of the sun and obviate the focusing of the solar rays. Certain sizes of these bricks are adapted to the building of conservatories, greenhouses, skylights, awnings, portes-cocheres, etc., and others are especially adapted to the building of walls, partitions for city houses,offices where both light and a partition are wanted, porches, cellar windows, etc.

Vaults, 8 yards in width, and walls 9 yards in height (maximum), can be constructed ; vaults and sides of greenhouses, conservatories, partitions, etc., inside of the above measurements, are entirely made of glass bricks without any iron framework ; above these dimensions, supports and stanchions are necessary.

A model conservatory erected with Falconnier's blown glass bricks was shown at the World's Columbian Exhibition, and received an award and a very favorable report.

The prize contest between *automobile vehicles*, arranged by the *Chicago Times-Herald*, and which was to have taken place on the 2d of November, was postponed on account of the inability of a number of the contestants to be in readiness for the test. The event was accordingly postponed and took place on November 28th.

Mr. J. De Benneville has succeeded in isolating and identifying several *new carbides of iron*, from specially prepared ternary alloys of iron, chromium and tungsten, and iron, chromium and molybdenum. His observations are regarded as having much importance in iron metallurgy.

BOOK NOTICES.

Aluminium, its History, Occurrence, Properties, Metallurgy and Applications. By Joseph W. Richards, A.C., Ph.D., etc. Third edition, revised and enlarged. Illustrated by forty-four engravings and two diagrams. Philadelphia: Henry Carey Baird & Co. London: Sampson Low, Marston & Co., Ltd. 1896. (Price, $6.)

It is evident, from a comparison of the present edition with its predecessors that the author has kept in close touch with every phase—scientific and industrial—of his subject. The second edition happened to appear most opportunely. The electric methods for the reduction of aluminium had just fairly begun to demonstrate their immense superiority over the chemical processes, which they have since completely supplanted; there was a widespread public interest in all that pertained to the then new metal, concerning which the most extravagant notions were entertained, and the most exaggerated claims were made. Of the book, it is not too much to say that its immediate and remarkable success, while in some measure ascribable to the peculiar circumstances above referred to, was, in much greater measure, due to the thoroughness and accuracy of the author's work. Not a single phase of the subject escaped his attention, and it has won for its author respect and admiration. There are few technical works of American origin which may compare with it, and none which excel it, in the conscientious work which has been bestowed upon it.

The present edition follows the same lines in treating the subject as its predecessor, and brings it up to date. Several of the chapters, notably the historical introduction, the discussion of the fundamental thermo-chemical considerations involved in the understanding of the electrical methods of reduction, the results of the electrical methods, and the important branch of the alloys of aluminium, have been largely revised or re-written. Taking the work as a whole, it is worthy of the highest praise.

The publisher, also, is entitled to mention for having issued it in a highly creditable manner. W.

The Electric Transmission of Energy. A Manual for the Design of Electrical Circuits. By A. V. Abbott, C.E., Chief Engineer Chicago Telephone Company. 586 pp., with nine folding plates. D. Van Nostrand Company, and Sampson Low, Marston & Co. $4.50.

In the preface the author modestly disclaims anything "strange or remarkable in the present volume," yet the book is a valuable addition to electrical literature. It is decidedly up to date. For instance, it contains drawings of the Lenox Avenue conduit in New York, and of the Love conduit in Washington, upon whose successful operation during this winter, perhaps, depends the future form of electric railway transmission in the large cities of the United States.

The drawings are clear, and the pictures of line appurtenances especially good. The reader is refreshed by the absence of a tiresome explanation of the principles of the dynamo, and is grateful to feel that at last he can be presumed to know something of electrical induction as well as of the multiplication table.

After discussing the line, measuring instruments, and methods of measurement, the question of the designing of electric circuits, as would be expected from the title, is given an extended treatment. The writer has brought together materials from numerous sources, and put them in such accessible shape as to deserve the gratitude of the designer. The seventy-eight tables and nine plates will be especially appreciated.

Regard has been had to both American and European practice. Why, among the notable instances of polyphase transmission, does the system Buelach-Oerlikon not appear? Both Sartori, in his "Trasmissione Elettrica," and S. P. Thompson, in his recent book, cite it, and with reason; for 13,000 volts between adjacent wires is a trifle unusual. Of American plants, those at Pomona, Redlands, Portland, Telluride, Concord and Niagara are described.

The value of the treatment of line design would have been much enhanced had the author proposed a definite problem of transmission, and then worked it out in every detail, thus illustrating the application of his formulæ and tables.

The subject of each section is printed in heavy type—a commendable feature. After the text follows an exhaustive index of seventeen pages.

Whenever the author leaves the distinctly practical side of his subject he is not so fortunate. One has the feeling that he is not very sure of his ground. The definitions of the volt and the coulomb, p. 223, the derivation of the coefficient of self-induction of a circular current, p. 317, entirely without regard to the area of the circle, the absence of the familiar sine of one-half the angle of deflection law in the discussion of the ballistic galvanometer, will serve as illustrative points. This criticism, however, does not affect the value of the book as a whole, but only the value of a minor part, of a part, indeed, that need not have appeared in a book bearing the title above given.

G. F. S.

Franklin Institute.

[*Proceedings of the stated meeting, held Wednesday, December 18, 1895.*]

HALL OF THE FRANKLIN INSTITUTE,
PHILADELPHIA, December 18, 1895.

JOS. M. WILSON, President, in the chair.

Present, 90 members and 14 visitors.

Additions to membership since last report, 16.

The resignation of Mr. J. C. Trautwine, Jr., from the Board of Managers was presented and accepted. Mr. C. Hartman Kuhn was elected to serve for the unexpired term.

The following nominations were made for officers, managers and committee men.

For *President*	(to serve one year), . . .	Joseph M. Wilson.
" *Vice-President*	(" three years), . . .	Chas. Bullock.
" *Secretary*	(to serve one year), . . .	Wm. H. Wahl.
" *Treasurer*	(" " "), . . .	Samuel Sartain.
" *Auditor*	(" three years), . . .	Samuel H. Needles.

For *Managers* (to serve three years).

Washington Jones,
Theo. D. Rand,
Isaac Norris,
Charles H. Banes;
Stacy Reeves,
F. Lynwood Garrison,
Thos. P. Conard,
Coleman Sellers,
Henry Gawthrop,
W. L. Boswell,
Jas. M. Dodge,
John G. Baker.

For members of the *Committee on Science and the Arts* (to serve three years).

Arthur Beardsley,
Hugo Bilgram,
Frank P. Brown,
John H. Cooper,
N. H. Edgerton,
G. M. Eldridge,
F. L. Garrison,
Reuben Haines,
W. N. Jennings,
Arthur Kitson,
Edward F. Moody,
E. Alex. Scott,
Coleman Sellers,
H. W. Spangler,
Wm. H. Wahl,
C. J. Reed.

Mr. Pedro G. Salom read a paper on Automobile Vehicles, with incidental reference to the recent prize contest arranged by the publishers of the Chicago *Times-Herald*. Mr. Salom illustrated his paper by the exhibition of a number of lantern pictures of various types of such vehicles, of American and foreign design, and by the exhibition of the Morris-Salom "Electrobat," No. 2, an electrically propelled vehicle, which was awarded the first prize, a gold medal, in the prize contest above referred to. The meeting voted to refer the Morris-Salom vehicle to the Committee on Science and the Arts for investigation and report. Mr. Salom's paper, with the discussion thereon, will appear in the *Journal*.

Mr. C. Francis Jenkins, of Washington, read a paper giving an account of the development of the art of reproducing, by photography and optical accessories, the movements and actions of living subjects, and illustrated the subject by means of the phantoscope, a projecting apparatus devised by him for this purpose. With this instrument Mr. Jenkins succeeded in reproducing, in life size, on the screen, the movements and actions of dancers, gymnasts, etc., with remarkable fidelity to nature.

On account of the lateness of the hour, a communication from Dr. Grimshaw and the report of the Secretary were omitted.

Adjourned.

Wm. H. Wahl, *Secretary*.

JOURNAL

OF THE

FRANKLIN INSTITUTE

OF THE STATE OF PENNSYLVANIA,

FOR THE PROMOTION OF THE MECHANIC ARTS.

VOL. CXLI. FEBRUARY, 1896. No. 2

THE Franklin Institute is not responsible for the statements and opinions advanced by contributors to the *Journal.*

COMMERCE AND DEEPWATERWAYS.*

BY PROF. LEWIS M. HAUPT, Consulting Engineer.

The lecturer was introduced by the Secretary of the Institute, and spoke as follows:

MEMBERS OF THE INSTITUTE, LADIES AND GENTLEMEN:

In attempting to present a subject having so many phases, I shall endeavor to direct attention first, to the great economies and practical utilities resulting from a liberal public policy towards our river and harbor improvements; second, to the wonderful developments and benefits which have followed the successful deepening of some of the "highways of commerce," and third, to the methods which may be applied to secure the rapid and economical removal of the bars obstructing our waterways; touching incidentally upon the relations of coastwise to foreign commerce, the limita tions of draft to tonnage, the importance of shorter and deeper links connecting our great water systems, the incalculable losses due to insufficient water in natural channels, and the lessons furnished by experience, both at home and abroad, resulting from increased commercial facilities.

---

* A lecture delivered before the Franklin Institute, December 13, 1895.

It has taken many years to impress the fact that the cheapest known method of transportation is by water, and that on the ocean the greatest economy is effected by the use of vessels of largest capacity. From this it follows that the price of every commodity imported or exported is affected by the size of the ship, and this in turn by the depth of water in the channels along her course. Hence the question of suitable depth becomes one of momentous importance to the commerce of the world, and often determines the supremacy of nations as of cities.

A few inches of sand across the ship's path imposes an effectual barrier to her progress, and may at times cause her entire destruction.

This question of the capacity of vessels is but another phase of the transportation problem, to secure the largest paying load at least cost for moving it, or, as it is more technically termed, the greatest ratio of live to dead load.

In rail transportation, the roadbed, rolling stock, stations, fuel, terminals and a host of employes constitute a large factor in the fixed charges (usually over 60 per cent.), while in water transportation, in natural channels, the roadbed is the free gift of God, the weight of the cargo and vessel is balanced by the buoyancy of the water, the fixed charges are relatively small, and the motor has merely to overcome the resistances of the air and water to the ship's passage through them. In many cases, as in rivers flowing to the sea, gravity provides the motor, and the cost of movement is hopelessly beyond reach of any figures possible in overland routes. For instance, the cost of transporting coal from Pittsburgh to New Orleans (2,000 miles) by the Ohio and Mississippi Rivers, including the return of empty barges, is accomplished at a profit to the carriers at 65 cents per ton, or $\frac{1}{3}$ mill per ton-mile, while the rate for the same coal from Pittsburgh to Lake Erie, with millions of tons in transit annually, is 8 mills with transfer, or 6·93 mills without; this is 20·8 times as much as by the river. If the uncertainty of delivery by water, in consequence of the "tie-ups" occasioned by droughts, were removed, the cost of fuel on the river banks would give to the manufacturers of the valley a very great advantage over other competitors not so favorably situated.

The penalties paid for this uncertainty are enormous, as will presently be shown.

This rate of $\frac{1}{3}$ mill per ton mile is, however, exceptionally low for an interior waterway in an unimproved condition throughout most of its course; yet the rate on the Great Lakes and on the ocean is even lower. Ocean freights are sometimes carried at $\frac{1}{5}$ mill per ton mile, while the lowest paying rail rates are about 4 mills, the average charges being very nearly 9. So far as rail and ocean commerce are concerned, therefore, it is manifest that these two systems can never encroach the one upon the territory of the other, nor can they ever hope to compete in rates; but it must follow that the freight will remain aboard vessel and penetrate the inmost recesses of the land unless special inducements or rates are made by rail, or excessive pilotage or port charges cause an earlier transfer of cargo to the more expensive carrier.

It is this principle which has established, with few exceptions, all the great maritime cities of the world at the head of navigation of bays, rivers and estuaries. It has built Tyre, Venice, Marseilles, Amsterdam, Hamburg, Libau, London, Liverpool, Glasgow, Boston, New York, Philadelphia, Baltimore, Savannah, New Orleans, Galveston, Chicago, Duluth and many other terminals.

It is, in general terms, therefore, an error to carry export freights by rail beyond the first port at which they may be conveniently shipped, for with the difference in rates of 20 to 1 the short cut to tidewater is undoubtedly the cheapest for all parties. To carry the freight in cars beyond this point and to use so expensive a plant for storage purpose is, to say the least, an extravagant policy.

But it may happen that no suitable harbor or place of transfer exists at the nearest point on tidal water, or that there are physical obstructions which render shipment both dangerous and expensive. At one of the Gulf ports, for instance, the cost of lighterage is stated to be $1.50 per ton, so that the charge for lading a 3,000 ton vessel in the "offing" would be $4,500. At the average rate of 9 mills per ton mile this freight could be hauled 166 miles further, provided it could then be shipped without lightering. In point of fact, much of it is carried over 300 miles further to New Orleans on the Mississippi, 113 miles from the sea, with towage and pilotage charges almost as great, doubtless to retain control of the freight and utilise the company's own terminals at this point. The cost of lighterage alone, at ocean rates, would carry the freight by sea 3.900 miles. Any port, therefore, that can secure a deep water channel over the bar, and thus eliminate these terminal expenses, and which is at the same time located near the centers of production, occupies a strategic commercial position, and hence it is that so much attention has been given by the Government to the Gulf coast, as being that which furnishes the shortest haul from the great grain fields of the West to the markets of the world as well as to our Eastern seaboard, and why money has been so lavishly spent at South Pass, Sabine Pass, Galveston and other places, to remove the bars obstructing commerce at these ports. Although $7,500,000 were spent by Capt. Jas. B. Eads and his associates in successfully deepening the South Pass to 30 feet, still the port and river charges constitute a barrier which limits the commercial movement of the Mississippi River, while at Galveston the struggle has been maintained with the sea for about a quarter of a century with the result that after spending probably $6,000,000, with more to follow, on jetties and dredging, a depth of only 19½ feet was reported as having been secured last October. The original depth over the outer bar was 12 to 12½ feet.

Here also the terminal charges for lightering over the bar have so restricted commerce as to have fully justified the lavish expenditure made in the effort to remove this persistent and difficult obstruction. But as the desired ultimate depth of 30 feet has not yet been attained, Congress has granted special concessions to private parties to improve the mouth of the Brazos River and Aransas Pass, that, if possible, the people of the South and West might work out their own salvation contemporaneously with the Government effort. Under these Acts, contracts are now being executed at both of these ports, which will be referred to later, our attention being confined at present to the benefits and economies of deep water in general.

The more deeply this phase of the subject is investigated, the more impressive becomes the conviction that the stimulus given to commerce by the deepening of her waterways is the basis of national prosperity. This conclusion gives to the appropriation for this purpose a pre-eminence over all others, and justifies, to the fullest extent, the levying of special taxes if necessary for this purpose. This policy is pursued by foreign countries with the most beneficial results, and it is carried so far as to subsidise steamship lines to develop new avenues of trade without opposition.

In 1892, the chairman of the Senate Committee on Commerce reported that "the total expenditure for water improvements on the lakes has amounted to about $30,000,000, approximately one-fifth of the annual saving effected in transportation. By the improvement of these great waterways freights have decreased from 15¾ cents a bushel for corn between Chicago and Buffalo in 1859, to 1·9 cents in 1890. Since then it has been carried for 1 cent per bushel for these 1,000 miles, and the tendencies are still lower.

In this country, a narrow partisanship condemns such propositions as unjustifiable prodigality, while conflicting transportation companies oppose the enlargement of our waterways on principle, erroneously assuming that they are injurious competitors.

These opposing forces will account for the comparatively undeveloped condition of our internal waterways. A few extracts from the testimony, taken by the Cullom Committee on Interstate Commerce, will serve to reveal some of the actual causes obstructing our commerce.

Mr. F. B. Thurber, of the New York Board of Trade, said:

"Canals should be modernised. For twenty-five or thirty years they have remained just as they were. * * * The water lines are, I may say, the salvation of this country, and should be developed and extended in every possible way. * * * The railroads have improved enormously, while little or no improvements have been made in our system of American waterways. * * * This is doubtless largely to be attributed to the adverse influence of railroad corporations in legislation. In Pennsylvania and other States they have bought up the canals and abolished them. Whenever a river and harbor bill is pending in Congress, the railroad representatives will vote millions for improvements which do not materially affect them; but when it comes to an item like the Hennepin Canal, which promises to be of benefit in extending our system of waterways, they are found voting solidly against it," etc.

Mr. Chas. Ridgely, President of the Springfield Iron Company, said, in regard to the importance of developing water-routes: "The cost of such improvements would come back to the people many times over, in the reduced rates of freight which they would secure, even if all the freight went, as now, by rail, and the canals were unused."

Hon. Thos. Updegraff, of Iowa: "I have more faith in water routes as cheapeners of transportation on interstate commerce than in all suggested means."

This is the general purport of some 90 witnesses, of whom 80 per cent. was in favor of improving our internal waterways, 17 per cent. was opposed, and 3 per cent. undecided. Of the 15 persons opposed, 10 were railroad officials, 3 farmers, 1 merchant and 1 machinist.

But the opinion entertained by some railroad managers as to the injurious effects of parallel waterways is giving place to the more enlightened belief that such competition is beneficial. This is evinced by many of the most prosperous railroad managers in this and other countries. While it is a very important factor in the commercial development of our resources, it is too broad to be considered at this time, and must be dismissed with the suggestion that the stock quotations taken in connection with the geographical position of the roads will serve to illustrate its truth.

RATES BY COUNTRY ROADS.

In strong contrast with the rates by water, as previously mentioned, it may be well to observe, in passing, the semi-official results recently reported by General Roy Stone, special agent of the Road Inquiry Office, concerning the cost of freight movements over our road system in various sections of the country. "The average cost of haulage over the roads in the United States is 25 cents per ton mile; in New England it is 32 cents; in the Middle and Southern States, 31 cents; in the Northern States, 27, and in the prairie country, 22 cents. The average length of haul in the Northern States is 6·9 miles, so that the total cost of the haul is $1.86 for each ton."

The total cost of the movement of our farm products reaches nearly $1,000,000,000, of which nearly two-thirds might be saved by merely improving the roads. There are many places where the rehabilitation of our canals would reduce this tax upon commerce still further, and, by increasing the ratio of water to land carriage, lower the through rate, while still giving the railroad a larger percentage of the tariff than it can now secure, and at the same time increase its tonnage and shorten its haul. Mr. Stone says: "We are handicapped in all the markets of the world by the enormous waste of labor in the primary transportation of our products and manufactures, while our home markets are restricted by difficulties in rural distribution which not infrequently clog all the channels of transportation, trade and finance."

Another benefit resulting from deeper internal waterways would be the increase in the amount and value of our exports, thus converting a deficit into a surplus, and making us a creditor instead of a debtor, paying our balances in goods and products instead of in gold, and stimulating our manufactures by the lower price of raw material provided from the home market. It thus extends its beneficent influences beyond the limits of the nation and assumes an international importance. These generalities are abundantly illustrated in the case of France, Germany and other countries.

RELATION OF DOMESTIC TO FOREIGN COMMERCE.

The internal commerce of a country is the basis of the external, and as its relative importance does not appear to be generally recognised, a few words in relation thereto may not be amiss. It is commonly believed that the foreign tonnage is the largest and most valuable adjunct to a seaport.

This fallacy doubtless arises from the fact that every ton of imports or exports is recorded, as most of it is taxed for revenues, and its value is carefully appraised, while the domestic tonnage is not generally reported, and the difficulty of securing statistics of this movement from official and reliable sources is very great; yet a careful examination of the reports of the various Boards of Trade, Census Reports, and other documents, leads to the conclusion that the domestic tonnage is not far from 75 per cent. of the entire tonnage of most of our ports. Taking our own case for example, we find that in 1892 the gross tonnage of Philadelphia was 14,572,292 tons, of which 3,788,781 only was foreign, or 25 per cent. In 1893 the total was 13,326,484 tons, of which 2,971,111, or only 22 per cent., was foreign. The rest, or 78 per cent., was coastwise. Of this traffic over 5,000,000 tons was coal, and about 1,000,000 petroleum.

In 1870 it was stated that the domestic commerce through the limited Delaware and Raritan Canal exceeded all the foreign tonnage to and from New York for that year.* Since then the foreign commerce of New York has expanded enormously, while the canals have been contracted by the failure to recognise their utilities and economies, and to enlarge their capacities to keep pace with the demands of modern vessels.

Another question of considerable importance, viz.:

THE RELATION OF DRAFT TO TONNAGE,

arises in connection with the projects to enlarge existing waterways. It is one which is almost indeterminate, since it grows with the additional facilities afforded. The tendency to cheapen transportation by carriage in bulk causes ship-owners to build larger vessels in anticipation of deeper drafts. On this point the late General O. M. Poe said:

"For thirty-five years I have watched the increase of the Great Lakes' commerce, but neither I nor any one else has been able to expand in ideas at the same rate. The wildest expectations of one year seem absurdly tame by the side of the actual facts of the next."

This statement is fully confirmed by the fact that in 1840

---

* Testimony of Gen. I. Wister before Interstate Commerce Committee.

Henry Clay denounced the Sault Canal project as "a work beyond the remotest settlement in the United States, if not in the moon," and yet the locks have since been enlarged thrice to accommodate the rapid strides in the traffic.

Last year the tonnage exceeded 13,000,000, yet the opening of the Canadian locks, by affording increased facilities, has enabled about 15,000,000 tons to be passed during the current year, which merely proves the old adage that *facilities create traffic.* By "facilities" is to be understood any economy resulting from reduced distances or time in transit, or at terminals, or from reduced rates.

The relation between draft and tonnage is more fully set forth in the annexed communication to the Board of Engineers appointed to select the best route from Baltimore to the sea.

UNITED STATES CUSTOM HOUSE,
BALTIMORE, November 26, 1894.

Thos. L. Casey, Brigadier-General, Chairman, Chesapeake and Delaware Canal Board, Washington, D. C.:

* * * The draft of vessels is not made a matter of record in this office, and I have, after consulting with competent persons, arranged the number of vessels embraced in the foregoing statement into four groups under certain respective drafts, which will probably serve as a guide to your deliberations.

I will also state that there is a large number of vessels engaged in the coasting trade, between this and other domestic ports, that are not obliged to enter or clear at the Custom House, representing as much as 2,000,000 tons, about 75 per cent. of which go North and bear the same relative proportion as to draft.

[SIGNED] JAS. A. DIFFENBAUGH,
Special Deputy Collector.

This is followed by a tabular statement of tonnage, foreign and coastwise, for several years, from which the following data are collated:

COASTWISE MOVEMENT FOR 1893 FOR PORT OF BALTIMORE.

	Under 10′ Draft.	10′ to 15′ Draft.	15′ to 20′.	Over 20′.	Total Reported at Custom House.
	Tons.	Tons.	Tons.	Tons.	
To and from Northern cities	29,911	145,641	487,754	205,237	868,543
Percentage	3%	17%	56%	24%	100%

It will be seen that *only 3 per cent.* is carried in vessels drawing 10 feet of water, while by far the greater portion requires from 15 to 20 feet, and that a depth of 20 feet would pass 75 per cent. of the tonnage. If the nondescript tonnage is 2,000,000, as stated for Baltimore alone, and we take 75 per cent. of it, or 1,500,000, and add it to the recorded tonnage alone, it gives a total movement from this one port for the year of 2,368,543 tons to and from *Northern* cities.

The domestic commerce of Delaware Bay and tributary waters, as reported by the various custom districts, after deducting 25 per cent. for foreign commerce, is 14,250,000 tons, while that of the Chesapeake Bay is 11,250,000 tons, making a total of 25,500,000 tons.

If 3 per cent. represents the limit of the present 10-foot canal it would equal 765,000 tons, which will be found to be about the average tonnage of the Chesapeake and Delaware Canal in the past ten years.

Were this canal deepened to 15 feet, it would then be able to pass 20 per cent., or 5,100,000 tons, and 20 feet would give it a capacity of 75 per cent., or 18,125,000 tons.

With this amount of commerce in sight at present, it is manifest that a very great reduction in rates could be allowed, and still leave a handsome profit to the owners.

Fifteen feet draft, or 5,000,000 tons at 20 cents, would yield a revenue of $1,000,000, and for an open waterway at tide level it would cost but little more to handle 5,000,000 than one-tenth this amount, so that the excess would be profit, and the rates could be reduced to a minimum, to great advantage to the commercial interests of this populous section. At 1 cent per ton mile, or 14 cents for the trip (which is still a high rate for canals) the revenue would be $700,000, the interest at 6 per cent. on $11,666,566, whereas the cost of the work with modern devices should not exceed $2,000,000.

An open waterway once built requires the minimum of expenditure for maintenance and operation, and the fixed charges are practically independent of the tonnage.

This work of enlargement, if undertaken, with the cooperation of the Government, would prove to be one of the most beneficent and profitable enterprises of our times, and would commend itself to all enterprising and public-spirited citizens. It would restore in great measure the declining commerce of this port, and increase the profitable tonnage of all railroads having terminals in these waters, by stimulating manufactures and increasing the ratio of growth.

Stevenson says the commercial value of a waterway increases as the cube of the depth, so that if the depth be doubled its value will be eightfold greater. This law must be restricted, however, within practical limits.

THE TYNE, ENGLAND.

Let us now note a few special instances of the benefits resulting from the deepening of waterways, and their results upon the adjacent territory, taking first one of the many valuable and instructive foreign precedents.

A case which is often cited, but which will bear repetition because of its moral, is that of the River Tyne, on the east coast of England. It is but a short stream extending from New Castle to the sea, about 19 miles of which are in tidal waters. In its original condition it was little better than a creek, and vessels were often stranded on the bars in 3 feet depths at low water. Frequently vessels drawing 17 or 18 feet were obliged to wait two or three months for favorable spring tides and winds to enable them to cross the bar; yet now the largest ships afloat can safely navigate this stream without detention at any stage of the tide. To secure this result, the sum of $20,000,000 has been spent by the Tyne Commission in dredging, building training-walls, piers and dry docks, and in providing warehouses and terminals. From 1860 to 1887 over 80,000,000 yards were dredged. At the beginning of the work the revenues derived from tolls and tonnage dues were far from sufficient to provide for the annual expense, and it became necessary either to borrow the money or permit the shipping to seek other ports having better facilities.

It was decided to borrow, and up to the end of 1882 the work was conducted on loans, which aggregated $18,365,000. Only $2,130,000 was expended out of revenue received from shipping. The result, however, has fully justified this policy, as the annual income has grown in 20 years from $455,000 to over $1,255,000. The results of these improvements, which have produced a depth of 30 feet, have been remarkable. In 1888 nearly 21,000 vessels entered and cleared, carrying 8,396,000 tons, which is about equal to the commerce of the Suez Canal. These improvements were not made by the Government, but under the admirable system of public works existing in Great Britain, which authorises local harbor commissions to levy a tonnage tax upon vessels, and to apply the revenues derived therefrom directly to the maintenance and improvement of the harbors. Thus, under the presidency of Sir Joseph Cowen and his Board, aided by their resident engineer, Mr. Philip J. Messent, to whom I am under obligation for many valuable data, these works have been successfully executed with so great benefit to the commerce and industries of that thrifty and popular center. A trip to Tynemouth reveals a succession of shipyards, warehouses, mills, factories, towns and cities skirting both banks of the river, which is almost unparalleled in the world, all due to the increase of depth in the river and on the bar to 30 feet mean low water.

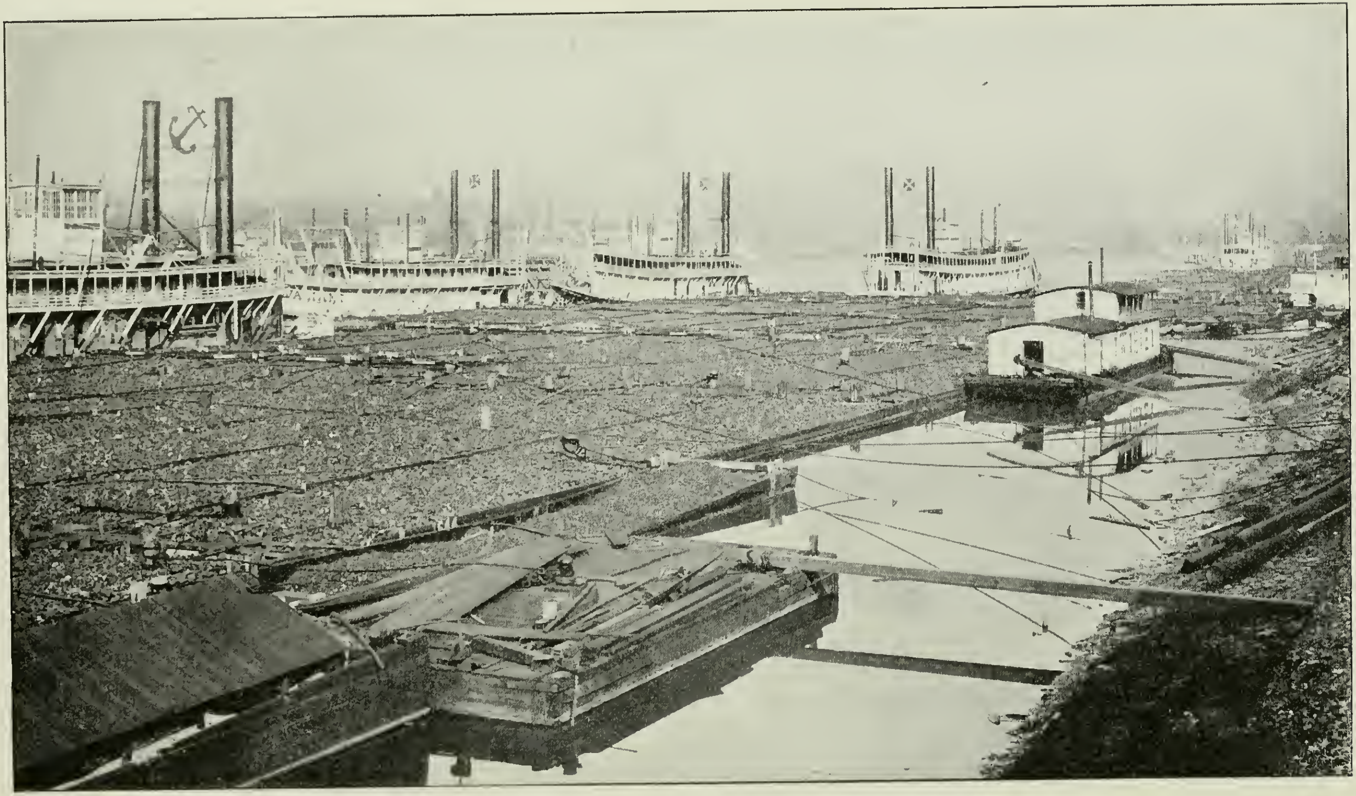
THE OHIO, BELOW PITTSBURGH.

Per contra, as in art, so in engineering, it often requires negative to produce positive results. The sinking of a propeller in the channel below the locks at the Sault so obstructed commerce as to leave no doubt about the propriety of still further enlargements in that direction.

The blockade of our seaports in 1813–14, and the destruction and sacking of the National Capital impressed upon our forefathers the importance of connecting the Chesapeake, Delaware and Raritan Bays by canals; and in the event of a war to-day with any foreign power, the absence of a passage for our heaviest gunboats would seriously cripple our defences and expose our coastwise cities to destruction. If the mere edict to construct such waterways could bring them into existence in a moment, it would then be issued, be the cost what it might, "but it would then be too late."*

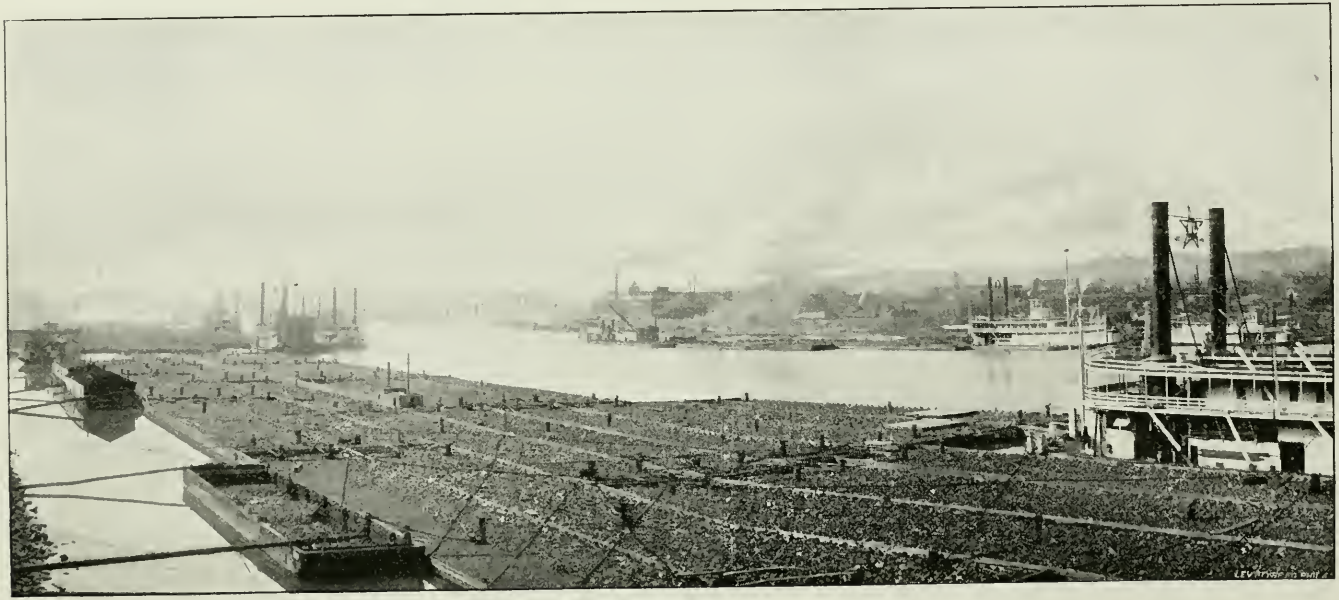
---

* Gen. Wm. P. Craighill, U.S.E.



Navigation on Ohio Suspended by Drought from April until December, 1895.—1,200,000 Tons of Coal. Value of Plant over $6,000,000. Daily Expense of Keeping it Afloat, $2,000.

Jour. Frank. Inst., Vol. CXLI. February, 1896. (*Haupt.*)



COAL TOWS IN THE DAVIS ISLAND POOL ON THE OHIO RIVER—AWAITING A "RISE" TO GO OUT.

One of the most impressive lessons to be derived from the absence of sufficient water for commerce is to be found in the experience of the communities on the upper Ohio River during the past season of exceptional drought.

The harbor of Pittsburgh, which is made by the movable dam at Davis Island, and the fixed dams of the Monongahela slackwater system forms a convenient basis in which to make up the tows of coal boats and barges which supply the Mississippi and its tributaries.

It is the custom to assemble these tows above the dam and await the pleasure of Pluvius to provide a flood with sufficient depth of water to carry them out. Sometimes the river rises to within a few inches of the requisite height, and then provokingly subsides. During the past season there has been no coal shipped by river between the 18th of April and the 28th of November (over seven months), and the accumulation of the product had gone on until the tonnage tied up exceeded that of any harbor in the world. For miles on both banks of the river the steamers and their fleets lined the shores, and the danger of their being frozen in all winter was imminent, when a heavy rain released 200,000 tons; but a part of these met a watery grave on the shoals of Dead Man's Ripple, a short distance below Pittsburgh.*

---

* *Quantities of Fruit Going to Waste.*—The Ohio River lower than it has been since 1860, with one exception.—Distilleries in Kentucky affected.

CINCINNATI, O., Oct. 15.—Millions of bushels of fruit are going to waste along the Ohio River, because of the close of navigation. Between this city and Evansville, 150,000 barrels of apples, in addition to potatoes and other produce, will be lost by decay.

At the little port of Amsterdam, Ind., 2,000 barrels of apples have been lying on the wharf for two weeks awaiting shipment.

The river is lower now than it has been since 1860, with one exception.

The continued drought in Central Kentucky is interfering seriously with the distillers. Glen's Creek, which is the only source of water supply for several distilleries, has gone dry, and a large number of men are out of employment.—*Ledger, October 16, 1895.*

* *Mishaps to Barges.*—Fifteen that were carrying coal sunk, and eight more are aground.

PITTSBURGH, November 28.—Nearly 5,000,000 bushels of coal was started down the river to-day, making a total going out on this rise of about 15,000,000 bushels. The river is now receding rapidly, and as there is no present

The extent of this congestion cannot be appreciated by one who has not seen it, and it is far-reaching in its effects, as it directly concerns the industries of millions of people. The actual value of the plant tied up in the harbor of Pittsburgh alone, as stated by Hon. John F. Dravo, Secretary of the Coal Exchange, on November 7th, 1895, was $6,310,000, as follows: "There are at the present time in Pittsburgh harbor about 1,200,000 tons of coal loaded on about 2,500 vessels:

2,500 vessels, average cost $900	$2,250,000
Cost of coal in Pittsburgh harbor	1,260,000
There are registered in this port about 80 towing steamers, average value, $30,000	2,400,000
Twenty passenger and other steamers, average value, $20,000	400,000
	$6,310,000

"At the present time it is costing about $2,000 per day to keep this tonnage afloat, besides interest on the investment."

Two thousand dollars per day is the interest on $40,000 at 5 per cent. In one month it represents $1,200,000—merely to keep the tows afloat, which is done by sprinkling sawdust over the surface of the river around the boats and pumping out the seepage from the interior. This "tie-up" of Nature has seriously crippled the entire valley, as the railroads cannot do more than maintain a partial supply, and the price of fuel has risen in some of the larger cities $1.00 a ton.

These are but a few of the consequent evils resulting

---

prospect of more water, the tows with 7-feet boats will, of necessity, have to tie up along the route before reaching Cincinnati.

A wreck at Dead Man's Island, near Sewickley, last night, caused a loss of about 250,000 bushels, involving the sinking of fifteen barges. The *Relief* grounded a barge, and the four other tugs, with barges following close in their wake, were piled up one after another in a confused mass. The channel, however, was cleared sufficiently to permit the tows leaving to-day to pass through safely.

The *Iron Age*, towing eight barges of iron and steel for Cairo, is aground at Freedom, and up to a late hour to-night had not succeeded in getting off. Her cargo represents about $240,000.—*Times, November 29, 1895.*

from the unimproved condition of the upper Ohio, which has been crying for relief for half a century.

As yet only the one dam is completed, at Davis' Island, 5½ miles below Pittsburgh, although another is now under contract at Beaver, some 23 miles below the first, leaving between the two a long stretch of unimproved navigation. These dams cost about $1,000,000 apiece. In contrast with this state of affairs, reference may be made to the work of improving the Great Kanawha by a similar system of movable dams, under the continuous supervision of General Wm. P. Craighill, now Chief of Engineers. Here the system will soon be completed, and will furnish a 6-foot navigation to Brownsville, with the result that, while the commerce of the river has greatly increased, that of the railroads has, contrary to their expectation, been expanded in like ratio. Nor is this an isolated instance where the improvement of the waterways has proven beneficial to railway traffic. In fact, the experience is general, and it is no uncommon thing to find railroads hauling crude products at a loss to maintain the traffic resulting from their use in manufactures.

Between the lowest profitable rate by rail and by water, there is a large margin for movement of raw materials by canals, which cannot be profitably handled otherwise, and which, but for the cheaper water rates, must lie dormant in the earth at the expense of their dependent industries.

For example, by a suitable waterway from the coal regions of western Pennsylvania to Lake Erie, which is now felt to be a necessity, it is found that "bituminous coal can be delivered in Chicago at $1.61½ per ton; in Duluth, at $1.50½; Detroit, at $1.38; to Canadian vessels at the head of the Welland Canal, at $1.20; and in New York City, via the Erie Canal, at $1.98; and the secretary of the Pittsburgh Canal Committee, Mr. John E. Shaw, adds that the economy on coal alone in six leading cities of the lake region would amount to $12,000,000 annually, representing, at 4 per cent., the interest on $300,000,000."

"A comparison of the selling price of bituminous coal in the lake and Canadian cities and New York harbor, will make apparent the commercial benefit from these proposed deep waterways.

"That the present or any proposed railroad system of overland carriage by rail can never bring about this enormous saving to commerce is also apparent.

"There are nine railroads operating wholly or in part between Pittsburgh and the Great Lakes. The total cost of road and equipment of these lines is $172,141,738.82. The average ton mile rate on all freight on said lines is about 6½ mills, which is below the ton mile rate on the ore and coal to and from the Pittsburgh district, and yet the financial statements of four of these roads has recently shown a net loss on their business; and as the lowest class of traffic has required a ton mile rate below the average of total freight carried, it is not hard to see that it would have been business economy for these railroads to have put a sufficient amount of the enormous cost of their roads into a canal and had it relieve them of this low-class freight."

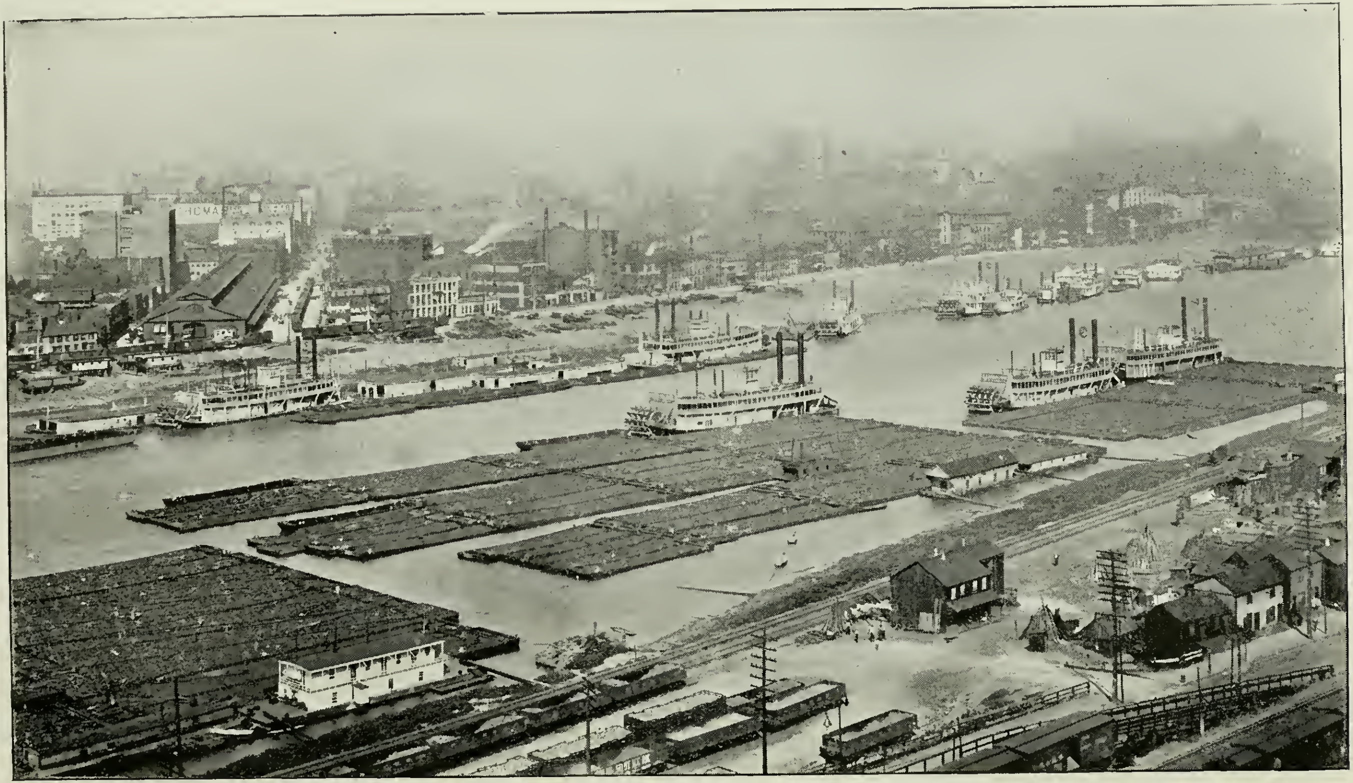
Some idea of the economies resulting from this proposed deep water canal, as based upon existing tonnage, may be obtained from the following statistics compiled by Mr. Shaw:

A saving of 77 cents per ton on the ore required for Allegheny County would be	$3,196,093 60
For Mahoning and Shenango Valleys it would be . .	1,382,875 14
Making a total of	$4,578,968 74
While the amount earned by the canal in carrying this ore at 35 and 15 cents, respectively, would aggregate	$1,455,998 85
The coal now shipped from western Pennsylvania to lake ports amounts to 7,761,891 tons, on which, at 72 cents per ton saved, the economy would be . .	5,588,861 58
At 30 cents per ton for transportation, the canal returns from this amount of coal would be	1,553,378 20
Or a total saved on the price of ore and coal at the points of consumption of	10,167,530 32
And a total earned for the canal of	3,009,379 05

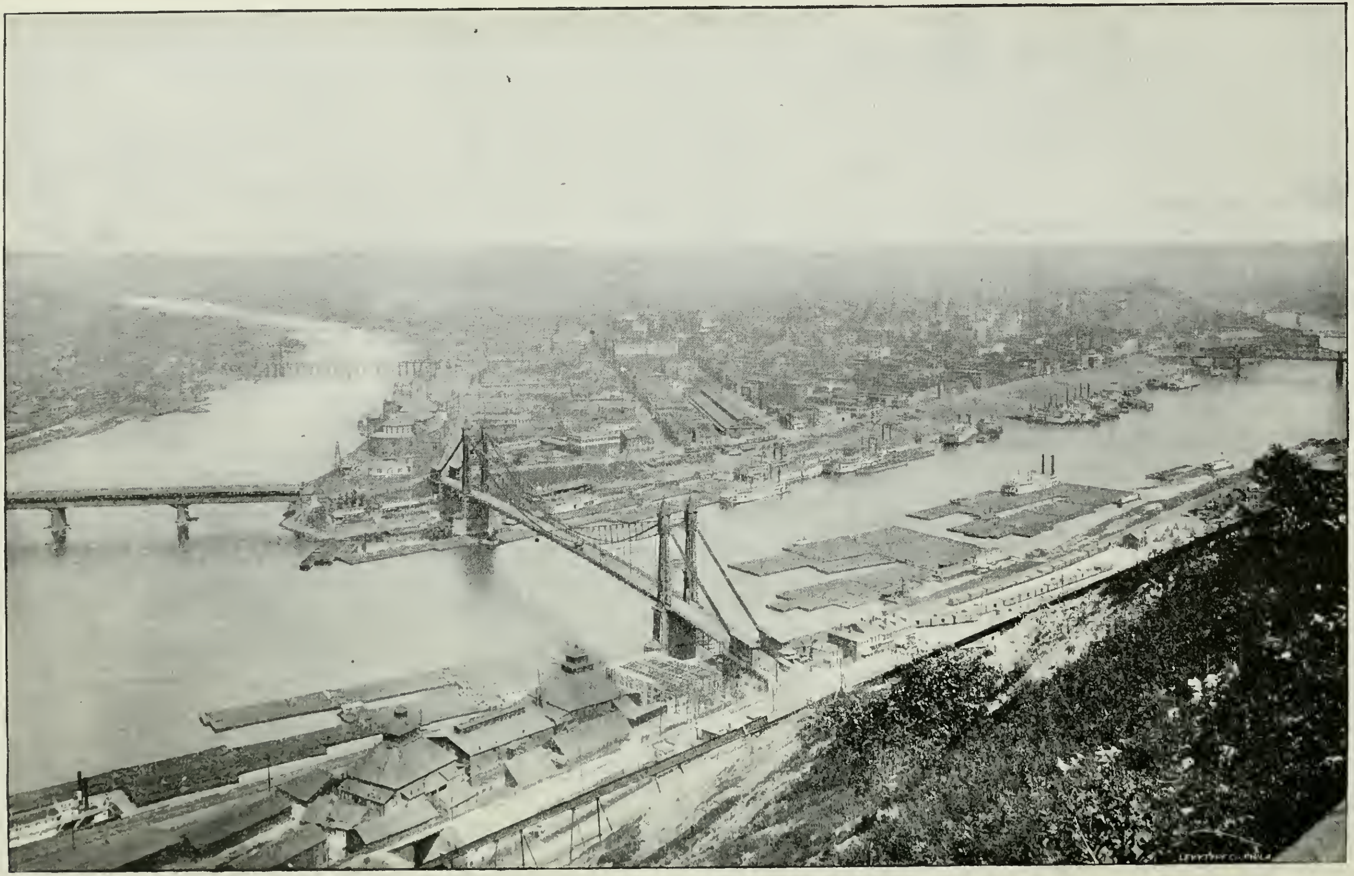
Being 6 per cent. on $50,000,000 from coal and ore alone.

A conservative estimate of the tonnage which would traverse this canal, if opened to-day to a depth of 15 feet, would be:

Jour. Frank. Inst., Vol. CXLI. February, 1896. *(Haupt.)*



Portion of Pittsburgh Harbor with Coal Fleets, Lining both Banks of the Monongahela River.



JUNCTION OF THE ALLEGHENY AND MONONGAHELA RIVERS FORMING THE OHIO AT PITTSBURGH, PA.

	Tons.
Ore	6,000,000
Coal	7,000,000
Limestone and miscellaneous	1,000,000
Coke and lumber	1,000,000
	15,000,000

At an average rate of 30 cents per ton, therefore, the revenue would be $4,500,000, while the economy effected each year in transportation would exceed $10,000,000. As there are many persons whose interests in other securities make them skeptical concerning such estimates as these on paper, it may be advisable to refer to the experience of the Suez Canal, which was so bitterly opposed by British diplomats, engineers and the press while in French hands. Now, however, since the control has crossed the English Channel, we find, in 1894, the gross receipts of the company were $15,390,230.60, as compared with $14,764,906.80 in 1893, and if the revenue from the tramway from Port Said to Ismalia and the lands and water company are eliminated, it will be found that the actual receipts from the vessels that used the canal were $650,800 higher than in the previous year. Expenses were $65,958.60 smaller than in 1893. Taking the whole of the charges of every kind, including the interest and sinking fund on the bonds, the 5 per cent. interest which is paid on the whole of the capital, and a sum of $90,000 for renewals and improvements, we get a total of $7,165,834.20, which, deducted from the gross revenue of $15,390,230.60, leaves $8,224,396.40. Out of this sum the council recommended the placing of $150,931.60 to the reserve, thus bringing it up to $1,150,931.60. Thus there remained for distribution among the shareholders $8,073,464.60, and each share, in addition to the 5 per cent., which is first paid, will receive for 1894 a dividend of $14.20. The gross yield on Suez Canal shares for last year consequently comes to $19.20, or 18 per cent., or, after deducting the tax, to $18 net. Tolls are now $1.85 per ton for the 100 miles.*

[*To be concluded.*]

---

* Consular Reports.

THE BUILDING STONES OF THE UNITED STATES.*

BY DR. WM. C. DAY.

The lecturer was introduced by the Secretary of the Institute, and spoke as follows:

MEMBERS OF THE INSTITUTE, LADIES AND GENTLEMEN:

It is my privilege this evening to call your attention to some of the more important features of the stone industry in the United States.

When we think of stone in relation to the uses to which it is put, we are inclined to look upon it as a building material, and while its application as such is, to be sure, more important than any other, we should not forget that there are other uses which the term building stone, in its proper sense, does not in the least suggest.

For example, stone for building, road-making, blast-furnace flux, and lime-burning, is frequently taken from one and the same quarry, and the particular one of the uses named, to which the stone is devoted at any given time, may simply be a question of demand for the time being.

While, from the strictly scientific standpoint, quite a large number of different kinds of stone are distinguished by separate names, from the commercial point of view, the number of distinctions is reduced, mainly for expediency, to six; these are: granite, sandstone, bluestone, limestone, marble and slate.

The term granite, which, scientifically, is definitely limited in meaning, is commercially used to include a number of varieties for which the scientific term, crystalline silicious rocks, would be more correct and sufficiently comprehensive. Among quarrymen producing the crystalline silicious rocks, the term granite is made to do a rather extended duty, and no fine distinctions of variety are recognised.

Sandstone is, commercially, a very different thing from the bluestone extensively quarried in New York, Pennsylvania and New Jersey, and used chiefly for curbing, flagging and paving in our large cities. The bluestone referred to is, however, simply a sub-variety of sandstone, and yet, if you were to tell a bluestone producer that he was quarrying sandstone, he would be inclined to smile at your supposed ignorance.

---

* A lecture delivered before the Franklin Institute.

While limestone and marble are chemically the same thing, namely, carbonate of calcium, or a mixture of carbonates of calcium and magnesium, physically, they are very different, and the widest possible difference exists in the uses to which they are put, and in the prices which they command.

In the stone trade, quite a number of names are in use which have merely a local significance, and which may, or may not, give an idea as to the nature of the stone. Thus, the name Conshohocken stone tells a Philadelphian at once what the material in question is, but it would probably mean much less to the resident of Chicago or St. Louis.

Stone, forming as it does so large a constituent of the earth's crust, is almost universally distributed; and when, in almost any locality, it is needed for ordinary foundation, building or road-making, it can be found ready at hand. When, however, we take into account considerations of durability, strength, beauty, capability of withstanding sudden changes of temperature, power to resist atmospheric agencies, etc., we may find that a stone capable of fulfilling all, or, indeed, only a few, of these conditions, must be brought from a distant locality. It thus happens that stone suitable for certain uses occurs naturally in a few spots only throughout our large country. This statement applies especially to marble, slate and the best varieties of granite.

Stone, in its natural bed in the earth, has, as a rule, but little value, and property which is supposed to contain even the more valuable kinds of stone may be purchased at a figure little, if any, above that which it commands for agricultural purposes.

Since, further, the land capable of yielding desirable stone is, in the majority of cases, for that very reason, unfit for cultivation, the price of undeveloped quarry property is often quite low. The high prices which stone often commands in the market are due to expenses of quarrying and dressing, and to transportation charges.

Historically considered, the stone-quarrying industry in this country dates back only to about the beginning of the present century, although stone, previous to this date, had been used, to a limited extent, for building purposes. The house of Deacon John Phillips, in Boston, built of granite boulders taken from the immediate vicinity, was erected about the year 1650, and it continued to stand until 1864. In the same city, the old Hancock house, since destroyed, was built in 1737, of Braintree granite, and between 1749 and 1754, also King's Chapel, still standing on the corner of School and Tremont Streets.

Previous to this, the granite boulders to be found in the neighborhood of Quincy had been used for minor purposes for some years, free of charge, until at last the inhabitants, assembled in town meeting, decreed that no person shall dig or carry off any stone on the said commons, or undivided lands, upon any account whatever, without license from the committee, upon penalty of the forfeiture of 10 shillings for every and each cartload so dug and carried away.

In 1825, quarries were opened at Quincy for the purpose of supplying granite for the construction of Bunker Hill Monument, and it is from this time that the business of quarrying granite assumed any real importance. While the Massachusetts quarries were the first to obtain granite systematically for building purposes, gneiss for curbing and paving was taken from quarries at Haddam Neck, Conn., as early as 1792. The product was used chiefly in Boston, New York, Albany and Baltimore.

The ready facilities of transportation by water to all of the important cities on the Atlantic Coast, and the excellent quality of the stone to be found on the coast of Maine, caused operations in this State to be started soon after the establishment of quarries at Quincy, Mass.

The quarrying of marble is said to have begun at New Milford, Conn., in 1800. Operations were actively carried on here for some years, but competition in Rutland, Vt., caused the shutting down of all operations in 1850.

Sandstone quarrying was conducted in 1665 at Middletown, Conn., operations being free to all until the townspeople decided to impose a tribute payable in wheat and peas for all stone taken away. The sandstone deposits were later acquired by purchase, and quarrying operations were very active between 1810 and 1820.

Slate quarries at Slateford, Pa., were opened in 1812. Slate quarrying in Vermont did not begin until 1845, when the manufacture of school slates was undertaken at Fair Haven.

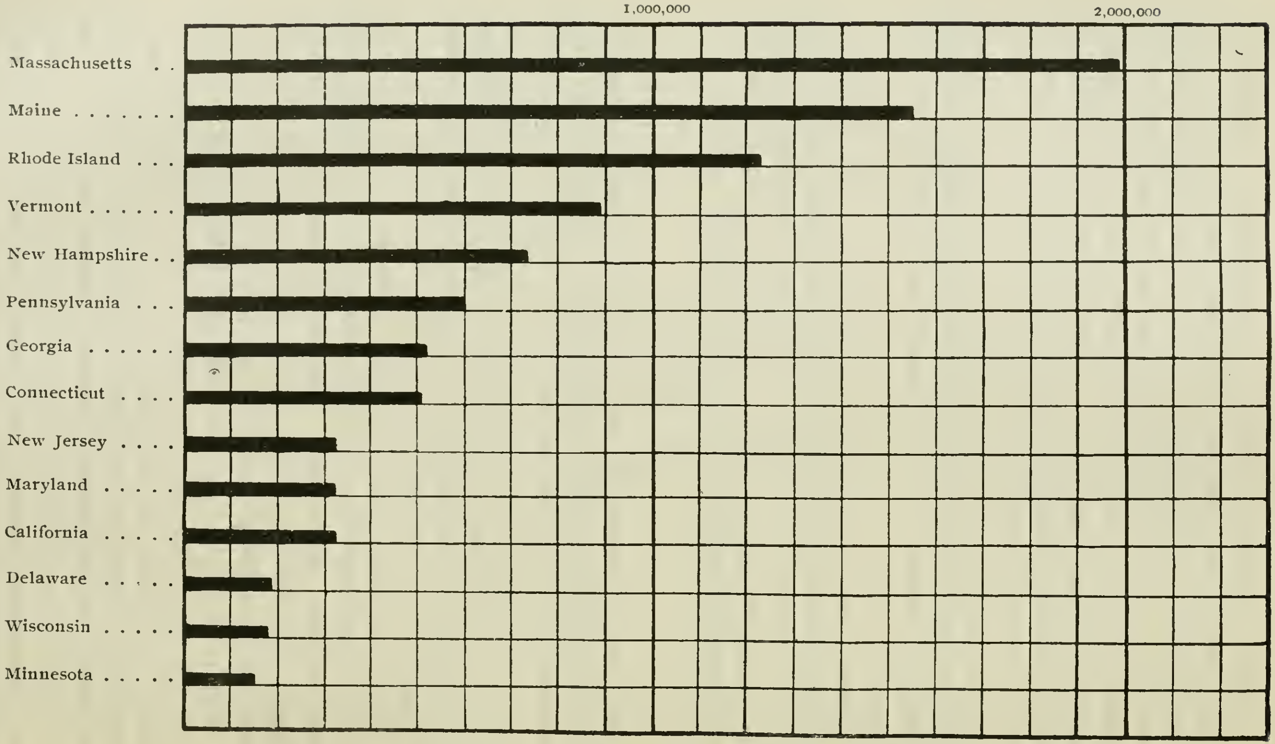
From these small beginnings the stone industry has increased, until it is, now, one of national importance, supplying most of our own needs and, though to a comparatively small extent, those of other countries, as in the case of slate, the exports of which are worthy of remark.

DISTRIBUTION.

The rocks from which we obtain our stone for building and other purposes have been formed in a variety of ways. The crystalline silicious rocks, which include the granites and allied rocks, have originated either from melted matter thrown out of the interior of the earth, or from sediments of a silicious nature which, to a greater or less extent, have undergone metamorphism.

The calcareous rocks have resulted from the hardening of the calcareous mud, produced by the breaking up of the shells of marine animals. They have also resulted, to some extent, from the deposition of calcareous matter from solution in water charged with carbonic acid gas.

The sandstones and clay slates, constituting the fragmental rocks, have been formed from the aggregation of particles of older rocks upon the beds of bodies of water, and have subsequently hardened into stone. The various varieties of sandstone are made up almost entirely of quartz granules cemented by materials of several kinds. While quartz granules are very much more common in sandstones than fragments of any other material, other minerals, such



Value of Granite Produced in the Various States during the Year 1894. (In millions of dollars.)

as feldspar and mica, are sometimes found. The nature of the cementing material in a sandstone is an all-important feature, and the sandstones are classed as argillaceous, calcareous, ferruginous, or silicious, according to the particular cement present. Some sandstones contain very little, if any, cementing material, the quartz particles being held together simply by strong pressure. This is the case with the celebrated Berea grit, of Berea, O.

The bluestone quarried abundantly in New York, New Jersey and Pennsylvania, owes its great hardness and durability to the fact that it consists of particles of silica cemented by silica, forming a stone very difficult to work, but well adapted for the purposes of paving and flagging, to which it is chiefly devoted.

Marble has been produced by the combined action of heat and pressure upon ordinary limestone, so that the latter, under these influences, has become crystalline.

Our roofing slate has also been the result of heat and pressure upon a silicious clay, which has thus become hardened, yielding a material having the property of splitting into thin sheets, and thus of rendering it applicable for roofing and for a very long and increasing list of other uses.

In considering the subject of the distribution of stone in the United States, we should expect to find those kinds which have been the result of metamorphism in those regions which have furnished the conditions of heat and high pressure. These conditions are incident to the process of mountain-making. Hence it is that we look for and, with a few exceptions, find the metamorphic rocks, namely, the granites, marbles and roofing slates, in the Appalachian, or the Rocky Mountain systems. The chart on the screen before you shows the values of the granite produced in the leading States during the year 1894. It is evident that most of the States thereon enumerated are traversed by either the Appalachian or the Rocky Mountain systems. The productive States, constituting the eastern section, have yielded 92·17 per cent. of the entire output. This section includes Maine, Massachusetts, Vermont, New Hampshire, Connecticut, Rhode Island, New York, New Jersey, Delaware, Pennsylvania, Maryland, Virginia, North and South Carolina and Georgia. The middle section includes Missouri, Minnesota, South Dakota, Wisconsin and Arkansas, the product of which amounted to 4·54 per cent. of the whole. The product of the western section, including the remaining States, amounted to 3·29 per cent. Intermediate between the eastern and the middle section is a continuous belt of States, which is totally unproductive of granite. These are: Michigan, Iowa, Illinois, Indiana, Ohio, Kentucky, West Virginia, Tennessee, Mississippi, Alabama and Louisiana. In two or three of these States, however, a future output of granite is not out of the question.

The following table shows the States producing marble:

VALUE OF MARBLE PRODUCTION BY STATES FOR THE YEAR 1894.

STATES.	Value.	STATES.	Value.
California	$13,420	Pennsylvania	$50,000
Georgia	724,385	Tennessee	231,796
Idaho	3,000	Vermont	1,500,399
Maryland	175,000		
New York	501,585	Total	$3,199,585

It is evident, from the States included here, that mountain systems are intimately connected with the formation of marble. It is very evident that Vermont is far in the lead of all States producing marble. New developments in marble production are being made in a number of States. The operations in Pickens County, Ga., are of particular interest, inasmuch as a coarse-grained, but highly crystalline marble, of quite a variety of beautiful colors, is being produced on the large scale, and is used largely for the interior decoration of buildings. It may be seen to good advantage in the Drexel Building in this city. The Georgia marble is exceedingly compact and non-absorptive, and although it would, of course, suffer from the effects of exposure to the atmosphere, it weathers uniformly and would therefore not become defaced. It is to be found, not only in the interior of the Drexel Building, but also on the roof, and its service in that situation will doubtless be watched with interest.

The texture of the Vermont marble is generally fine-grained and sometimes saccharoidal, though in this respect, it is inferior to the Italian marbles. Its color varies from white to blue through various shades.

The Tennessee marble, so highly prized for purposes of interior decoration, comes, for the greater part, from Knox and Hawkins Counties, in that State, and presents a great variety of color. It takes a very beautiful and lasting polish. The stone is beginning to be used for exterior construction, and some grades appear to give entire satisfaction. Methods of quarrying are still, in many places, in a comparatively crude state, and the industry is in its infancy, with apparently plenty of room for the judicious investment of more capital.

VALUE OF SLATE PRODUCTION IN 1894, BY STATES.

STATES.	ROOFING.		Other Purposes, Value.	Total Value.
	Squares.	Value.		
California	900	$5,850	—	$5,850
Georgia	5,000	22,500	—	22,500
Maine	24,690	123,937	$22,901	146,838
Maryland	39,460	150,568	2,500	153,068
New Jersey	375	1,050	—	1,050
New York	7,955	42,092	2,450	44,542
Pennsylvania	411,550	1,380,430	239,728	1,620,158
Vermont	214,337	455,860	202,307	658,167
Virginia	33,955	118,851	19,300	138,151
Total	738,222	2,301,138	489,186	2,790,324

The table before you shows the States producing slate. A line drawn from Piscataquis County, Me., to Polk County, Ga., and approximately following the coast line, passes through all the important slate-producing localities of the country.

Pennsylvania shows great prominence as a slate-producing State. For roofing purposes, the celebrated Peach Bottom slates, taken from a narrow belt in York County, Pa., and extending into Harford County, Md., cannot be excelled. This slate has been exposed on buildings for twenty-five years without showing any change. The belt is quite narrow, and the dip, in some cases, almost vertical, thus necessitating deep quarries, which are costly to work. At present more quarrying is being done on the Maryland side of the line than in Pennsylvania.

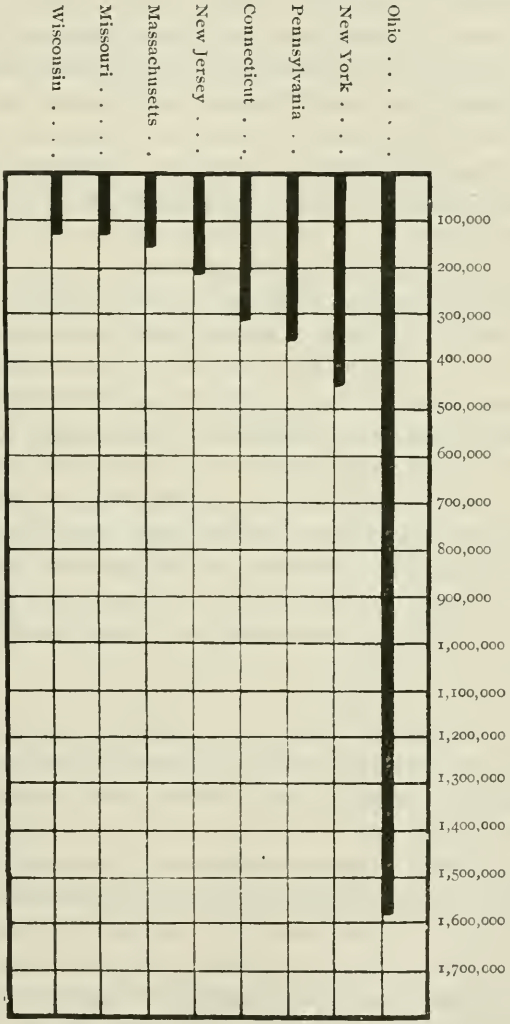
The slate-producing belt in Pennsylvania is divided conveniently into a number of regions, known as the Bangor, the Lehigh, the Northampton hard vein, and the Pen Argyl. The most important is the Bangor, which is entirely in Northampton County.

Although red slate occurs in Pennsylvania, the only place in the country at which it was quarried in 1894 was Washington County, N. Y. This, to the best of my knowledge, is the only locality in the world producing red slate, which, on account of its scarcity, brings a high price.

The slate of Vermont presents quite a variety in color, namely, various shades of green and purple. The so-called sea-green slate is produced in comparatively large quantities; it is easily quarried, but commands a low price.

In the production of sandstone, Ohio is seen by the chart to be far in advance of all other States, New York standing second. The prominence of Ohio is due to the vast operations conducted in the deposits of the so-called Berea grit, which is famous for building purposes, and for its value for grindstones and other products used for abrasive purposes. This stone is a fine-grained, very homogeneous sandstone, of a buff or bluish-gray color, evenly bedded. The different layers are quite distinct, and adhere to each other only very slightly. Slabs only 1 or 2 inches thick are used without hesitation, owing to the great strength of the stone.

The absence of cementing material makes the stone particularly well adapted for abrasive purposes, as it has no disposition to glaze, and thus destroy its usefulness. The Berea stone contains iron pyrites, which necessitate careful selection. On long exposure, however, most of this will become yellowish from oxidation of the iron; but this so-called mellowing with age is claimed as an advantage, and, unless it occurs in blotches, it is no disadvantage. The quarries at Berea, where the most improved appliances are liberally used, are, perhaps, the most interesting. About 40 acres at Berea have been quarried over, and recently a large addition to the quarry land has been made by the operating company.



Value of Sandstone Produced in the Various States during the Year 1894.
(In millions of dollars).

The Potsdam sandstone of New York possesses exceptionally fine properties in every way, and stands very high in the opinion of experts.

Limestone, other than marble, is quarried in forty different States and Territories, and, from the standpoint of total value of annual output, is the most important kind of stone. The large production of limestone is due to the variety and importance of its uses, which include building, road-making, lime-burning and blast furnace flux. The total value of the limestone product to the quarrymen who produced it is over $16,500,000.

One of the most interesting limestones for building purposes is the so-called Bedford oölitic stone of Lawrence County, Ind. Although these quarries have been worked for a few years only, the stone is well known in all the more important cities. It is formed of small, round grains, compactly held together by calcite. The supply of this stone is inexhaustible. Its light color renders it liable to bad staining when used in large manufacturing cities, but this fact does not seem to interfere with its popularity. The prominence of Pennsylvania as a limestone State is due to the large quantities used for burning into lime, and for blast furnace flux, rather than for stone used for building purposes.

METHODS OF QUARRYING.

The methods of quarrying stone are determined by a variety of conditions, such as the nature of the stone itself, the way it occurs in its natural bed, the uses to which it is to be put, etc.

In Shurtleff's history of Boston, it is recorded that one of the first stone buildings erected was the house of Deacon John Phillips. This was built about the year 1650, and remained standing until 1864. It was built of granite boulders found in the immediate vicinity. The methods of preparing these boulders for use was to build fires around them, and then to drop heavy iron balls on them from a considerable height, thus breaking them into sufficiently small fragments. This method of quarrying, if it may be so designated, may be regarded as one of the first to be applied in this country. While vast strides have been made in quarrying since that time, it is true, nevertheless, that some of the methods in use to-day are still very crude. This is notably the case in the quarrying of bluestone in Ulster County, N. Y. The work there is done largely by men whose sole possessions are a few of the simplest tools, such as crow-bars, picks and shovels, and sometimes even these are leased. The simplicity of the method of quarrying used is due to the manner in which the stone occurs, requiring merely to be dislodged from its resting-place. The stone occurs in thin beds with convenient joints, and it is, consequently, easily removed. Operating, as these men do, on any and everybody's land, no capital is required, and the land itself is of little value save for the stone to be taken from it.

In quarrying limestone for use as a blast furnace flux, or for burning into lime, the form and physical condition of the fragments is of no moment, and the most powerful explosives, such as nitro-glycerine in its various forms, are freely used, a liberal shattering of the stone being thus obtained. If, however, the stone is to be quarried in a condition suitable for fine building or ornamental work, the use of explosives must, in general, be as limited as possible. In quarrying marble, the use of explosives is at present universally condemned, not as the result of *a priori* considerations, but rather of actual experiments, some of which have been very costly. In some cases, Carrara marble, quarried by the use of explosives, has been found to disintegrate rapidly, and this is ascribed by experts to changes in physical condition produced by blasting. These changes may not show themselves at once, but may be revealed later in a very disappointing way.

Blasting is more of a necessity in quarrying granite, owing to the extreme hardness of the stone, and the consequent difficulty of working it. The best quarrymen, however, exercise great care and discretion in the use of powder.

A system of blasting, known as the Knox rock-blasting system, has come into quite general use within a few years.

The results obtained are those which were sought for by the method known as Lewising, but the Knox process is safer and quicker, takes less powder, and, for certain kinds of stone, gives sound blocks as the result of the blast, besides leaving a smooth wall-face for future operations. A round hole is first drilled to the required depth, and into this is driven a reamer, which cuts V-shaped grooves, on opposite sides, to the full depth of the hole. A number of such holes are drilled along the line which the fracture is to follow, and in line with the grooves. The charge is then inserted, and the tamping is done so as to have an air-space as great as possible between the tamping and the charge. The explosive has thus the greatest chance to produce expansion, not only from the gases generated, but also from the air present. The explosion, being directed in the line of the grooves, causes very little shattering, and rectangular blocks may be secured without loss of valuable stock.

In the hands of the Cleveland Stone Company, at its Berea quarries, the system appears to be invaluable. It would seem as though one might almost stand on the block to be blasted out without danger, so little spalling is produced. Among granite producers the system does not appear to have made great headway, but at Barre, Vt., one of the firms quarrying there reports uniform success with its use.

Within the past few years a number of noteworthy experiments have been made in blasting granite with very large charges. In 1887, at Granite Bend, Mo., a shaft 35 feet deep, with communicating channels running in several directions at the bottom, was charged with 32,700 pounds of powder; the explosion of this immense charge broke up stone enough to last the firm for fifty years. A similar plan was used at Stone Mountain, near Atlanta, Ga. This mountain seems to be simply one solid mass of granite, covered here and there only with patches of soil. After a very large blast had been fired, earthquake-like rumblings were heard within the mountain for a week or more afterwards, before equilibrium became again established.

My time will permit of a consideration only of the more important details involved in quarrying.

The bedded structure of stratified rocks is of vast importance to the quarryman, since the different beds or layers are easily separated from each other. If these beds are of a convenient thickness, the ease of working is much enhanced, but if they happen to be of great thickness, requiring splitting with wedges, they may not be of great advantage.

If these beds are horizontal, the process of quarrying is much simplified, since the work then consists in cutting vertically down. This is true of a number of sandstone quarries; for example, those at Berea, Ohio. One disadvantage of this, however, is that the quarrymen can tell nothing about what is deeper down. This is not the case where the beds have been tilted up at a considerable angle, since the qualities of stone in different layers can be determined from an examination of the exposed edges of the different beds at the surface of the ground.

At West Rutland, Vt., the marble quarries have the benefit of this condition, but the expense of quarrying is greater, and resembles mining, inasmuch as at a considerable depth tunnelling has to be resorted to.

Not only do the stratified rocks split easily in the stratification planes, but the same is true also of marble, in which the stratification of the original limestone deposit has not been entirely modified by metamorphic action.

In granite no bedding exists, but advantage is taken of fractures, called joints, which permit the rock to be taken out more readily. Different systems of joints intersect each other, thus facilitating the breaking up of blocks in rectangular or other shapes. Block and sheet quarries are those in which joints divide the rock into natural blocks and sheets, of which advantage is taken by the quarryman.

Frequently, in granite quarries, the only machinery used consists of drills and derricks. Channelling machines are used occasionally, and then only in getting out the most valuable stone. The hardness of granite is such as to make the use of these machines too expensive. In marble and sandstone quarries, channelling machines are freely used. The following illustration will serve to give a fair idea of the channeller.

The channeller, running on a track back and forth, over the quarry floor cuts grooves in the stone 2 inches wide and 4 to 6 feet in depth. Holes are then drilled horizontally by means of so-called gadding machines at the bottom of a block, which is then forced out by means of wedges. These drills work by either steam or compressed air. In the case of the Ingersoll drill they operate by striking blows, while the diamond drill operates by boring. The operation of the latter is very rapid.

The next illustration shows a channeller at work in a marble quarry. In dressing, carving and polishing marble and granite, a number of improvements have recently been made. In carving both granite and marble a number of attempts have been made to discover an instrument or machine which would successfully take the place of the long-used mallet and chisel, which yield results so slowly. Success at last appears to have been, at least partially, if not wholly, attained by the MacCoy pneumatic tool, which was invented a few years ago, and which the Franklin Institute has honored by the award of the John Scott medal. This instrument is actuated, as its name indicates, by air pressure; it is held in the hand and is guided over the tracing to be carved, its pointed or chisel-edged tool striking very rapid blows. Workmen who use it claim that the rapid jarring of the hand becomes very unpleasant, and some of them are decidedly opposed to it on that account. It is employed to some extent in carving granite, but to a much greater extent with marble, with which it is certainly very effective.

In grinding granite, the abrasive material now almost exclusively used is either chilled-iron globules, steel emery, or crushed steel. A coarse grade is needed at first, then a finer kind, and lastly fine emery. Final polishing is done in much the same way as grinding, except that a felt-covered disc is used instead of an iron one, and putty powder mixed with a little water instead of coarse grinding materials.

Granite for columns, baluster-posts and urns, is now generally turned on lathes, some of which take a shaft of granite 25 feet long and 5 feet in diameter. The granite is cut away by the wedge-like action of a steel disc, set at quite an angle with the stone, and running on an automatic carriage. The discs are revolved by the pressure of the stone as it slowly turns in the lathes.

The scientific examination of rocks, for the purpose of determining their structure, is an exceedingly important process, in connection with the question of determining the applicability of the material to various economic uses. It is not long since the science of petrology, in its development, was limited to the simplest methods of acquiring knowledge of the intimate structure of rocks. These methods involved the use of a pocket lens, chemical analysis, and determinations of hardness, specific gravity and the like. Chemical analysis of the mineral aggregations constituting rocks is, of course, desirable; but, in many cases, the results of such analysis, if conducted on the rock as a whole, and not upon separate constituents, are of comparatively little value. For, while analysis may tell correctly the composition of the rock as a whole, it may tell nothing of the constituent minerals, their physical condition, or the manner in which they are held together. The hardness of a stone, from the economic standpoint, is a very different thing from the hardness of its constituent minerals. These minerals may be quite hard themselves, and yet, if not firmly held together in a rock, the latter may, as a whole, be quite soft.

Specific gravity determinations are of value, since the strength and absorptive properties of a stone depend upon the density. The more dense the stone, usually, the stronger it is, and the less absorptive of moisture.

The introduction of the microscope into the study of the structure of rocks occurred about the year 1867, although the method of grinding rocks into thin sections was used as early as 1831, for the purpose of studying microscopically the minute internal structure of fossil plants. The advantages of a microscopical study of rocks are very apparent at the present day, not only to petrology as a science, but also in its bearing on questions concerning the applicability of stone for building and other purposes.

For the purpose of illustrating the use of the microscope and polariser in examining sections of rock, I have a few specimens which I submit for your inspection.

The methods of testing stone for building are at present not satisfactory; but doubtless, in course of time, microscopical examination and other means will add much that is desirable. Very little is done to determine the conduct of the stone under the influence of fire, frost, weathering, and the sudden cooling from an intensely heated condition, to which stone is frequently subjected during a conflagration, by flooding with water from fire engines. The principal test to which stones are at present subjected is that of compressive strength. The value of such a test is either overestimated or not sufficiently well understood, as a rule. A freshly quarried stone will almost invariably stand vastly more pressure than it will be called upon to bear. It is of more value to know what a stone will bear after many seasons of exposure to heat, frost and moisture.

A knowledge of the porosity of a stone is of importance, since the more porous it is, the more water it can absorb, and hence, the more liable it will be to disintegrate under the expansive action of water in freezing. It is the opinion of high authorities to-day that no test of stone is equal to an examination of natural outcrops, or of buildings of long standing, of which it forms a part.

NOTE.—For the historical data in this lecture I am indebted to George P. Merrill's work on "Building and Ornamental Stone." The reports of the Tenth and Eleventh Censuses have also been used.

THE MODERN OFFICE BUILDING.[1]

BY BARR FERREE.

A lecture delivered before the Franklin Institute, November 15, 1895.

[*Concluded from vol. cxli, p. 71.*]

The utmost diversity exists in the structure and the detail of the supporting frame in the skeleton construction. This variety is dependent, in a measure, upon the special conditions arising in each building; but it is largely due to the individual preferences of the designing engineer. No extended series of tests have ever been made as to the relative merits of the various columns, girders and beams employed in modern work, though special tests have been made in some particular instances. Nothing in the way of comparative tests has, however, been made.[45] As a matter of fact, therefore, the use of certain forms depends more on the preference of the engineer and the adaptability of special shapes, than upon an absolute knowledge of their intrinsic merits.

Although the details of the construction frequently differ widely in buildings employing the same structural methods, certain general principles underlie the selection of the section of the columns. These principles have been well elucidated by Mr. C. T. Purdy, who has designed the steel frames of many of the notable buildings of Chicago. According to this authority, the advantages, to be considered in a building column are: (1) cost and availability; (2) shopwork and workmanship of column; (3) ability to transfer loads to center of column; eccentric loading; (4) convenient connections of floor systems; (5) relation of size of section to small columns; (6) fireproofing capabilities of the section.[46]

---

[1] In undertaking to treat so large a subject as the modern office building in all its phases, economic, structural and æsthetic, within the scope of a single article, it is obvious that only the most summary review can be attempted. In order that the reader, who may be desirous of pursuing the subject further, may at once place his hand upon the latest literature on the subject, references have been made, in the foot-notes, to recent articles and papers in the professional journals, in which fuller accounts of the points under discussion may be found. The foot-notes appended to this paper are not, therefore, offered as authorities for the statements contained in it, but as keys to more extended studies of the subjects. The references are not, in any case, to be taken in a bibliographic sense, nor is any pretence made to do more than cover the latest American literature in a most summary fashion.

[45] An exhaustive series of tests, largely through the generosity of the Carnegie Steel Company and the Continental Iron Works, are about to be undertaken by a committee of engineers and architects.

Many sorts of structural columns are upon the market, each having its supporters and its particular advantages. The conditions under which these columns are used are so exacting and so varied, that of none of them can it be said that it is *the* column to use in all circumstances. Local conditions and cost and availability are more likely to determine the selection of a particular column, especially of a type that has long been in use, rather than some of the newer types, whose advantages may be offset by an increased cost, or, if it is a patented column, by the difficulty of securing it when wanted. In the following table the commoner sorts of columns are named and classified by the number of rows of rivets each requires.

One row: Larimer column.

Two rows: Z-bar column without covers.

Four rows: channel column with plates or latticed; 4-section Phœnix column; Gray column; Keystone octagonal column.

Six rows: Z-bar column with single covers.

Eight rows: box column of plates and angles; latticed angle column; 8-section Phoenix column.

Ten rows: Z-bar column with double covers.

In addition to these shapes, compound or complex columns are used under special circumstances. Special forms of the standard types have also been introduced to meet special requirements.

All these columns are now made in wrought steel. Prior to the introduction of this material into building operations, columns of cast iron were employed. These are still frequently used, but modern engineering practice does not encourage it. While this material has some advantages, it is very uncertain, and its liability to fracture renders it dangerous to use.[47]

---

[46] C. T. Purdy: "The Steel Skeleton Type of High Building," *Engineering News*, December 5, 1891, *seq*.

Although the particular section of the column in high buildings is without influence upon the design, some representative buildings are grouped below as illustrative of recent methods.

Cast Columns.—Chicago : Manhattan, Leiter, Tacoma, Auditorium, the Rookery, Phenix, Owings, Unity—all relatively early high office buildings.

Z-Bar Columns.—Chicago: The Fair, Y. M. C. A., Isabella, Pontiac, Caxton, Venetian, new Monadnock (skeleton part), Champlain, Marquette, Stock Exchange, old Monadnock, Great Northern Hotel, Woman's Temple, Ashland Block, Marshall Field, Rand-McNally, Boyce, Hartford, Columbus Memorial, Atwood; Pittsburg: Carnegie.

Z-Bar and Phœnix Columns.—Chicago: Old Colony (special shapes), Schiller Theatre.

Box Columns of Plates and Angles.—Chicago: New York Life.

Channels and Plates.—Chicago: Fort Dearborn (lower floors of plate and angles, then channels and plates; upper stories of latticed channels).

Plates and Angles.—Chicago: Masonic Temple, Teutonic.

Gray Columns.—Chicago: Reliance, Fisher, Steinway Hall; Columbus, O.: Wyandotte.

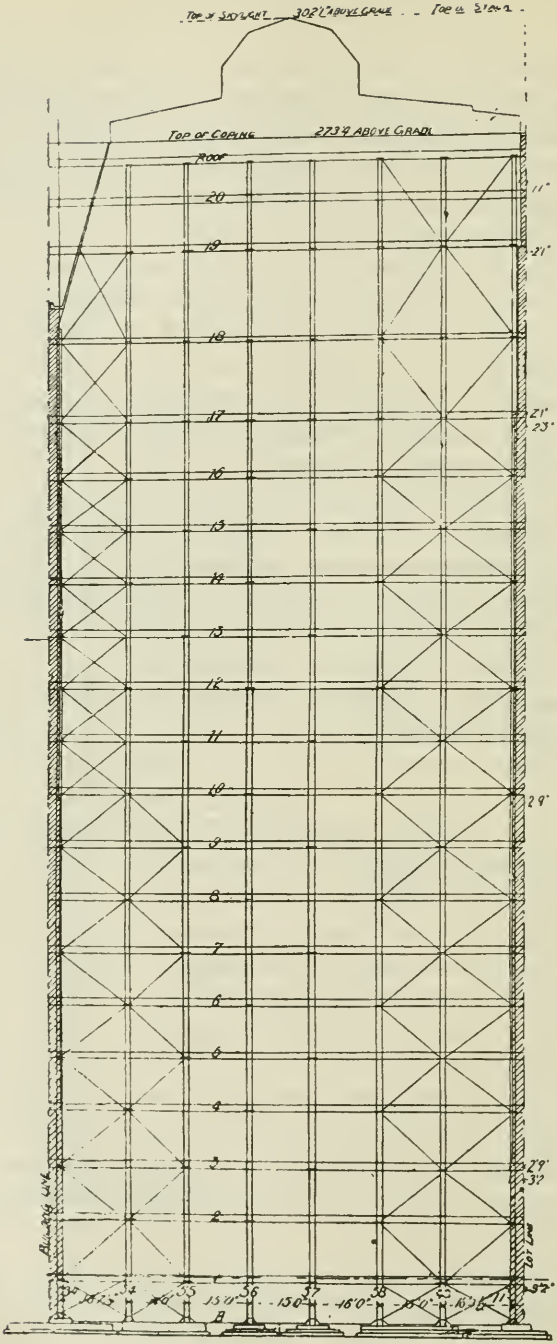
Larimer Columns.—Chicago: Newberry Library (not an office building).

Cast Iron and Riveted Columns.—New York: Manhattan (cast columns to sixth floor).

In buildings of great height and relatively small area, the steel frame of columns and girders is not usually con-

---

[47] "Cast Iron Columns in High Buildings," *Engineering News*, May 24, 1894. An exhaustive study of cast iron was contributed by J. B. Johnson to the *Transactions of the American Society of Civil Engineers*, **22**, 91.



Vertical cross-section, Masonic Temple, Chicago.

sidered sufficient to resist the force of wind pressure.[48] The frame is, therefore, often braced, though in low buildings, and in high ones of large lateral dimensions, it is frequently omitted. The Masonic Temple, Chicago, of twenty-one stories, 273 feet high and 19,224 square feet area, is provided with a system of rod-bracing inserted at each side of the elevators. The Stock Exchange, of the same city, on the other hand, of thirteen stories, 173 feet high and with a floor area of 18,000 square feet, has no wind bracing whatever. As in every department of the mechanics of high building, engineering practice differs greatly on this point, and much difference exists, not only as to the methods of resisting the wind forces, but even as to their amount and application.

Four general methods are in ordinary use, though the details of application frequently differ. These are: (1) sway-rods, or diagonal braces, connecting the columns diagonally between single floors; (2) the same, running through two stories, cutting the intermediate girder at the center of the diagonals (both systems are used in the Masonic Temple, Chicago, the sway-rods being connected with I-beams between the columns and below the floor system[49]); (3) portal arches (Old Colony Building, Chicago[50]); and (4) knee-braces, not an advantageous form (Isabella Building, Chicago; also, in a modified form, in the Fort Dearborn Building). The steel frame is sometimes braced by making the joints of the columns, usually in two-story sections, break at alternate stories (new Havemeyer Building, New York). The value of this method is, however, problematical. The selection of the type of wind bracing will depend, to a very considerable extent, upon the openings of the building, the location of the doors, partitions, and the like.

---

[48] W. H. Bixby: "Wind Pressure in Engineering Construction." Appendix C, of the Report of September 29, 1894, of the Special Army Engineer Board, as to the Maximum Span Practical for Suspension Bridges. Reprinted in *Engineering News*, March 14, 1895. H. H. Quimby: "Wind Pressure in High Buildings," *Transactions of the American Society of Civil Engineers*, **27**, 221. G. B. Waite: "Wind Bracing in High Buildings," *ibid.*, **33**, 190.

[49] *Engineering Record*, January 21, 1893.

[50] *Engineering News*, December 21, 1893.

The skeleton frame is, by its construction, a well-braced structure. It is not remarkable, therefore, that only the slightest vibration and deviation from the perpendicular have been noted in the best-built office buildings, even the highest. Some very careful observations made in the Monadnock Block, Chicago, showed a very slight vibration in heavy wind-storms.

The construction of the floors of office buildings, including the size and dimensions of the girders, their connection with the columns, the filling-in of the spaces between the girders and beams, and the laying of the floors, require as much care and forethought as the erection of the columns. In designing floors, the engineer has to consider the dead loads, or permanent weights of the building, and the live loads, or movable weights.[51] These factors are treated in the building laws of our leading cities, and the scientific phases of the loading of beams have been carefully studied and the results tabulated in many engineering publications.

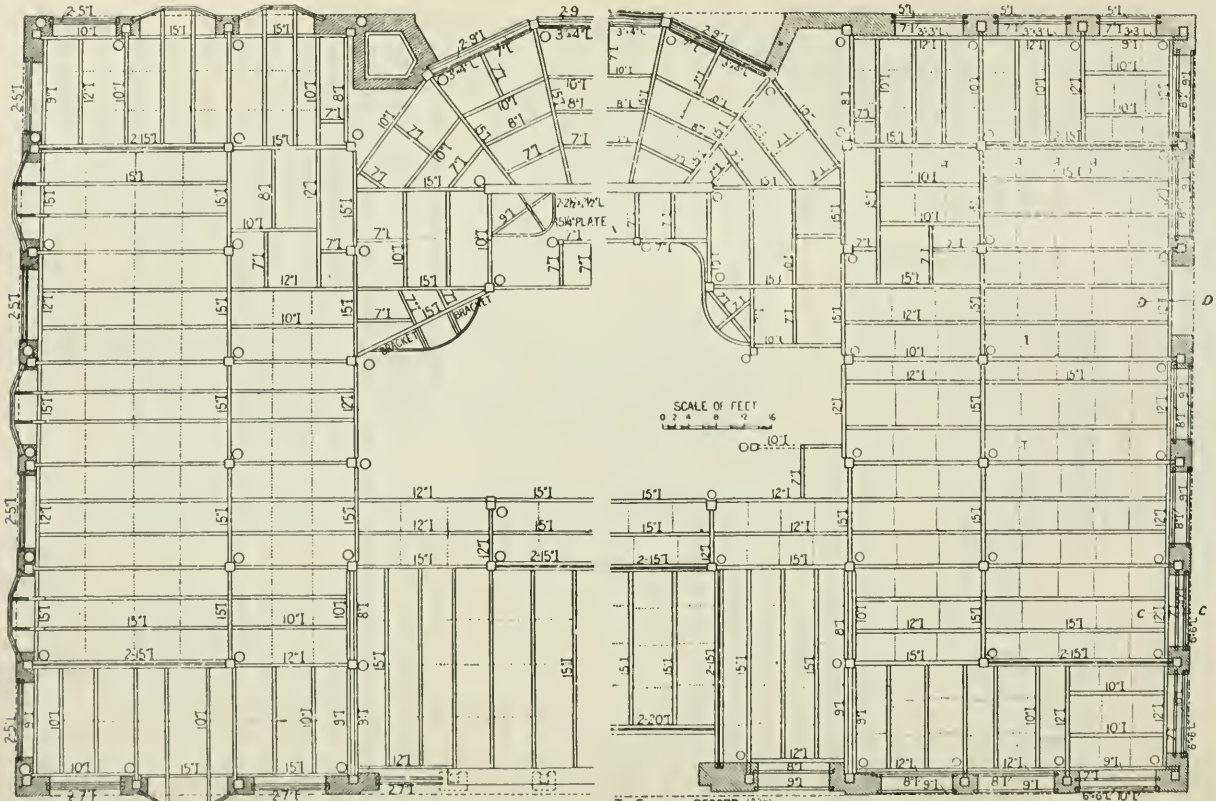
The stability of the frame, as well as of the floor itself, depends largely upon the advantages for good connections provided by the section of the column; and this, as before remarked, is one of the important considerations that must be taken into account in determining the class of column to be used.

Although the utmost diversity exists in the manner of filling-in the spaces between the beams of the floor, arches of fire-clay are now almost universally used.[52] They are fireproof, waterproof, have a flat upper and lower surface, are lighter than the solid brick arch, are free from shrinkage, can be made of any depth, and may be used for large and

---

[51] Jenney and Mundie: "Live Loads and Supports in Office Buildings" (New York Life, Chicago); *American Architect*, Feb. 10, 1894; also March 10, 1894; C. H. Blackall: "Live Loads in Office Buildings," *American Architect*, August 26, 1893.

[52] A summary of the more notable tests made on fireproof flooring will be found in the series, "Fireproof Floor Arches," by George Hill, *Brickbuilder*, January, 1895, *seq.* G. Hill: "Tests of Fire proof Flooring Material," *Transactions of the American Society of Civil Engineers*, **34**, 493. "Bericht des Gewölbe-Ausschusses." Sonderabdruck aus der Zeitschrift des Oesterr.-Ingenieur- und Architekten-Vereins, Wien, 1895.



THE ENGINEERING RECORD (420)

Beam plans and details of framing, Masonic Temple, Chicago. Half plan of second floor to left; Half plan of fourth floor to right.

short spans. Soft tile or porous terra-cotta, a mixture of clay, sawdust or other combustible material, is much used for floor arches. Concrete is also employed, but brick is now seldom used. Combination floors, of iron troughs and concrete, known as the Pencoyd corrugated flooring; or of iron or steel arches and concrete, in the system invented by Mr. Poulson;[53] or wire and concrete, in the Roebling[54] system; or wire and composition, in the Metropolitan system;[55] or corrugated iron and beams[56] are also used, as well as a Spanish method known in this country as the Guastavino tile arch, in which the floor arches are made of thin tile cemented together in a solid mass.[57] In almost all these systems, except the last, which are patented, a great variety of forms and devices in making the arch have been introduced.

Without entering into a discussion of the various sorts of floor arches now used in the office buildings, it is sufficient to remark that a typical floor consists of flat arches between the beams, covered on top with a layer of concrete, upon which wooden sleepers are embedded, which, in turn, are covered by a hardwood floor. In the hollow space underneath the floor-boards the gas and water pipes are placed.

In designing the steel frame, an essential point the engineer must keep in view is its enclosure within a fireproofing material. Properly braced, and often without additional bracing, the steel frame offers every requirement of stability; yet, unless it is encased within fireproofing, sufficiently thick to prevent injury to the metal by fire, or by the introduction of water, it fails in the first element of availability. This, indeed, is the crucial test of the stability of the modern office building. Structurally, though the problems are frequently complicated, there is nothing in

---

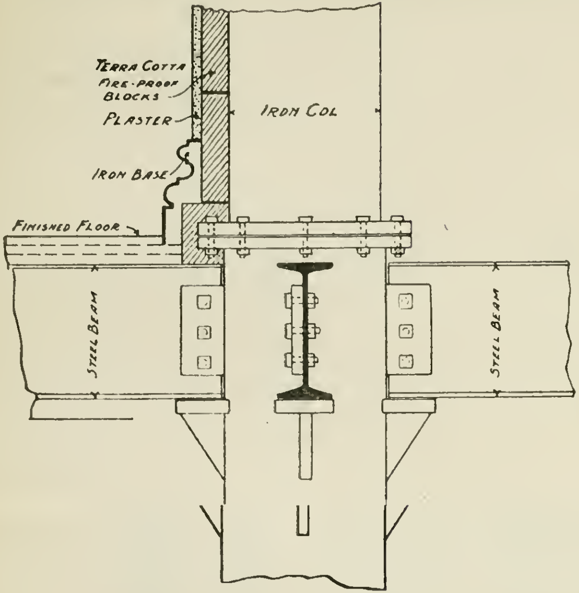
[53] N. Poulson: "A New Fireproof Construction," *American Architect*, March 25, 1893.

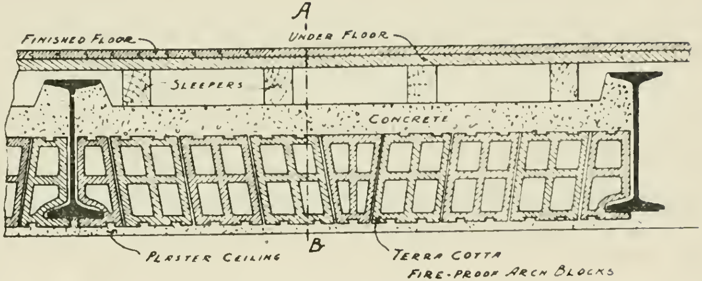
[54] *Engineering News*, July 18, 1895.

[55] *Ibid.*, October 25, 1894.

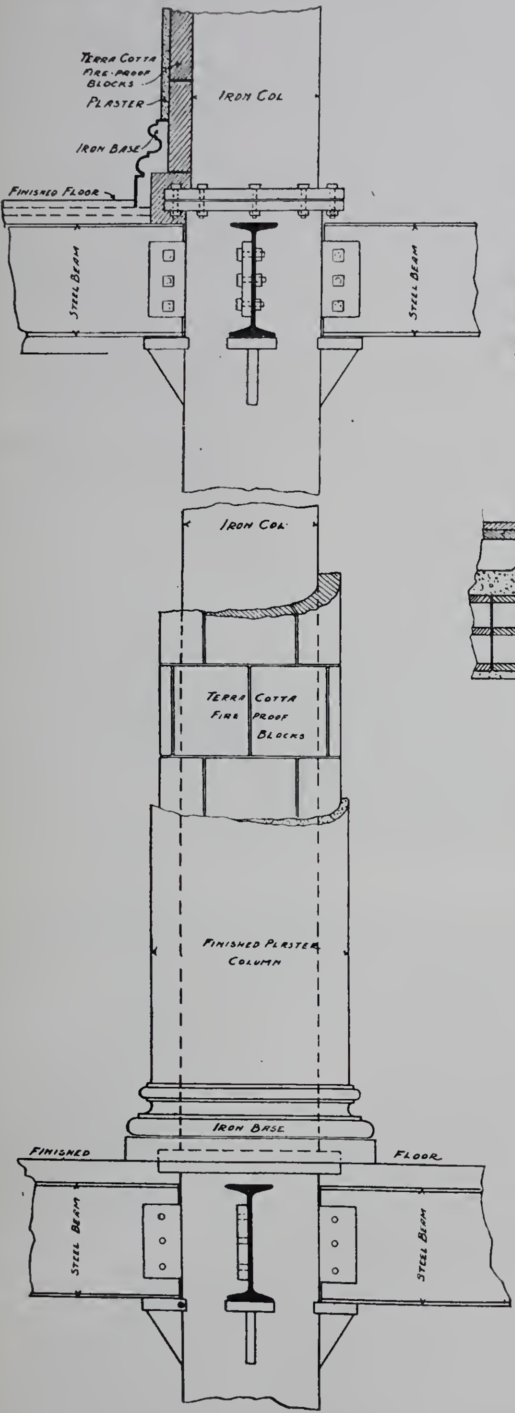
[56] H. B. Seely: "A New System of Fireproof Construction," *American Architect*, December 15, 1894.

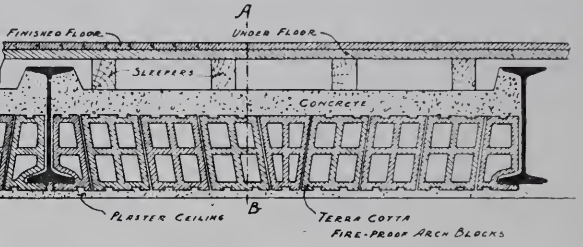
[57] R. Guastavino: "Cohesive Construction," *American Architect*, August 26, 1893; *Inland Architect*, May, 1893.



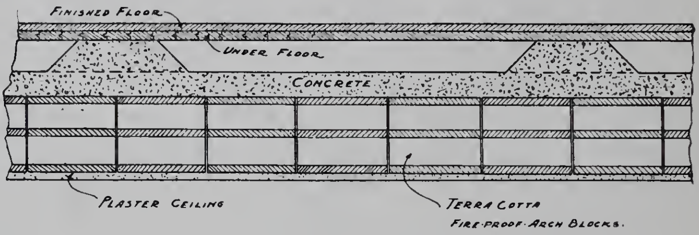


·TRANSVERSE SECTION·





·Transverse Section·



·Longitudinal Section·A-B·

New York Commercial Buildings.

East Washington Place Broadway Waverly Place Mercer St. N.Y.

Details of Construction

Robert Maynicke
Architect
111 Fifth Ave N.Y

any part of the work that modern engineering practice is not thoroughly competent to handle. It has not, however, yet been demonstrated how long these buildings will endure.[58] It is true the skeleton system has been used too short a time to enable any practical experience to throw any light on this point; but it is strange that no attempt has been made to examine the state of the metal in the older buildings of this type.

The question is of more moment since the modern office building is a structure whose period of existence is intended to far outlast that of the buildings it replaces. The amounts now invested in them are so large that nothing short of an almost permanent duration can render them profitable.

So far as present experience goes, the modern office building has amply satisfied all the claims made for it, when the construction has been good and thorough, and of the most approved type. It has been demonstrated several times (fires in Temple Court,[59] Edison and World Buildings, New York; Athletic Club,[60] Schiller Theatre,[61] Chicago,) that fires originating in one place can be confined to the room in which they occur, or, at the furthest, to the adjacent apartments. It has been shown, also, that, even where the fire has been a severe one, as in the Chicago Athletic Club, the structure of the building can escape without serious damage.[62] On the other hand, early and imperfect methods of fireproofing, as in the Manhattan Savings Bank, New York, are almost as unsatisfactory and as useless as no fireproofing at all.

The most zealous opponents to the high buildings are the fire departments. It is doubtless true that the fire departments of all our great cities would be unable to cope with a destructive fire in a very high building, owing to the lack of water pressure and the absence of special apparatus designed for use in such emergencies. On the other hand, the necessity of protecting these buildings against such dangers has certainly resulted in very considerable improvements in their erection, which have been manifested, not only in high buildings themselves, but in less costly structures. There can be no question at all but that the average of fire-resisting qualities in our modern cities has been greatly increased since the introduction of the skeleton system of construction, just as it is equally certain that these buildings are the safest structures we have, in any sense. This fact is generally overlooked by the fire chiefs in their criticisms on these buildings, and by popular critics who are not always disposed to accept them at their true worth.

---

[58] C. H. Blackall: "The Endurance of Structural Metal Work;" *Brickbuilder*, November, 1894.

[59] *Engineering News*, April 6, 13, 1893.

[60] *Ibid.*, November 24, December 1, 1892; January 12, 1893; *Inland Architect*, December, 1892.

[61] *American Architect*, April 28, 1894.

[62] "A Practical Test of Fireproofing," (Lumber Exchange, Minneapolis), *Inland Architect*, August, 1891; C. H. Bebb: "Fire Losses in Fireproof Buildings," *Engineering Magazine*, February, 1893.

The danger the office building is most subject to is not from within, but from without; that is to say, from the older and smaller buildings immediately surrounding it, or what is called the "exposure risks." There can be no question at all but that the safety of our cities is greatly increased by the continued erection of modern office buildings.[63]

PART III.

The design of the office building falls naturally into two great divisions: the structure and the architectural form. The former belongs to the engineer, the latter to the architect. The engineer has a necessary part in the design of the office building, inasmuch as his services are essential for the making of the foundations and the erection of the steel skeleton. To him belongs, also, the preparation of the frame for the coating of stone, or of brick or terra-cotta, and similar mechanical matters. These problems are so complicated and varied as to require the services of a specialist.

---

[63] Edward Atkinson: "Fire Risks on Tall Office Buildings," *Engineering Magazine*, May, 1892; J. M. Carrère: "Interior Fireproof Construction," *ibid.*, October, 1892; T. M. Clark: "Skeleton Construction and the Fire Department," *American Architect*, October 20, 1894; P. B. Wright: "Fireproof Construction and the Practice of American Architects," *American Architect*, August 19, 1893; "The Reduction in Cost of Fireproof Construction," *Engineering News*, May 10, 1894.

But because the engineer is rightly employed for the engineering of the high building, it must not be supposed that the architect may be ignorant of his duties or independent of his work. Every structural detail must be studied and understood by the architect. The relations of the two are co-ordinate, and each must know the other's province, and keep the other's purpose in view as well as his own.

That this is not always so, the history of modern office buildings often too clearly shows. It is not unusual for an architect to prepare his design on his drawing-board, and then send for an engineer to arrange its construction for him. On the other hand, it would be easy to point out designs apparently made by an engineer, and certainly carried out without the supervision of an educated architect. That there is more or less friction between the architect and the engineer; that the architect looks upon the engineer as too "practical," the engineer upon the architect as too visionary, is a fact not to be denied by those who have watched the development of the two professions. Only by the warmest sympathy and constant co-operation can the design of an office building be carried out in a proper spirit and with satisfactory results.

The exterior of a building is generally the criterion by which its success is measured. It is unreasonable that this should be so, for few structures—and especially few modern structures—are built for external show. But the office buildings have so little to offer within, in the way of ornament or of art, that the general public, and perhaps the architectural public, have fallen into the habit of judging them by their façades. A not unnatural consequence has been that a finely designed office building has now a greater commercial value than one that is badly designed; a good-looking building is thought more of than an ill-looking structure; and so the façade has a monetary value in these buildings which it does not always have in other structures.

From the commercial side of the question, it is quite as necessary to develop the artistic aspects of the high buildings as the structural. And, certainly, it is a monstrous architectural sin to put up buildings whose single merit shall be their size, and whose chief distinction shall be their hideousness. It is true we have many buildings, distributed throughout the cities of our land, of which no more can be said; but, with a wider appreciation of the value of æsthetics in commercial buildings, there must come a change for the better. Those that have been built must needs remain where they are; but those that are to come must, inevitably, show a betterment in design, as they will, unquestionably, show a betterment in construction.[64]

The structure of a building lies at the basis of its design. This is a fundamental fact in architectural æsthetics. Now, in a sense, the modern office building does not show its structure, either within or without; the steel columns and girders and beams whereon it is carried are covered up by the exterior surfacing or by the fireproofing or coating within. It is impossible to tell a solid wall from one built on the skeleton principle, and the structure of a hybrid or complex wall is equally invisible. How, then, it may be asked, can we have a successful high design, if, at the outset, a fundamental principle of design is ignored? This question has been asked many times, and architects have learnedly discussed this point without, it must be admitted, throwing much light on it.[65] But the question need not be asked in this way. The structure is, indeed, the basis of the design in the high building, as in the low one; but this does not call for the unveiling of the metal skeleton, nor for a frank display of the material of the structure. The *structure* may be shown, but the *materials* are necessarily hidden.[66]

---

[64] Barr Ferree: "The High Building and Its Art," *Scribner's Magazine*, March, 1894.

[65] Thomas Hastings: "High Buildings and Good Architecture," *American Architect*, November 17, 1894.

[66] Barr Ferree: "Structure and Material in High Design," *Brickbuilder*, March, 1894.

For it is admitted on all hands that steel and iron are impossible materials for high structures unless they be covered with a fireproof material. That, indeed, is one condition of their serviceableness. A naked steel column would be a source of constant danger. It would suffer deterioration from dampness and from contact with the atmosphere, and a fire would be fatal to its stability. A high building of any sort, in which the steel lines of the columns and girders would form a feature of the external design, would be too dangerous to warrant erection. We cannot, then, show the material of our building in the design, though we may, in a sense, show its structure.

Not only are there structural reasons prohibiting the direct employment of the metal frame as a basis in the design of high buildings, but those structures in which the architectural framework has been reduced to the smallest limit, so that the building is little more than a skeleton of brick or terra-cotta, show how unsatisfactory such a treatment is æsthetically. The Reliance Building, in Chicago, is, perhaps, the most notable attempt yet made to reduce the amount of the enclosing material to a minimum, and the design is scarcely more than a huge house of glass divided by horizontal and vertical lines of white enamelled brick. The Fisher Building, in the same city, and the Mabley Building, in Detroit, are other examples illustrating the same tendency, though in not quite so pronounced a fashion as in the first instance. It is a good principle in architecture that a building should not only be firm and strong, but that it should seem so. This reasonable requirement is not fulfilled in these designs. A high office building requires an appearance of being built solidly to produce the best effect, or, indeed, to produce an architectural effect. This, however, does not excuse the exaggerated effect of heaviness and stability that may be seen in some designs, and which is quite as bad as extreme tenuity. Perfect naturalness of expression, good taste and an understanding of the structural requirements of the problem are all the architect needs in designing his façades.

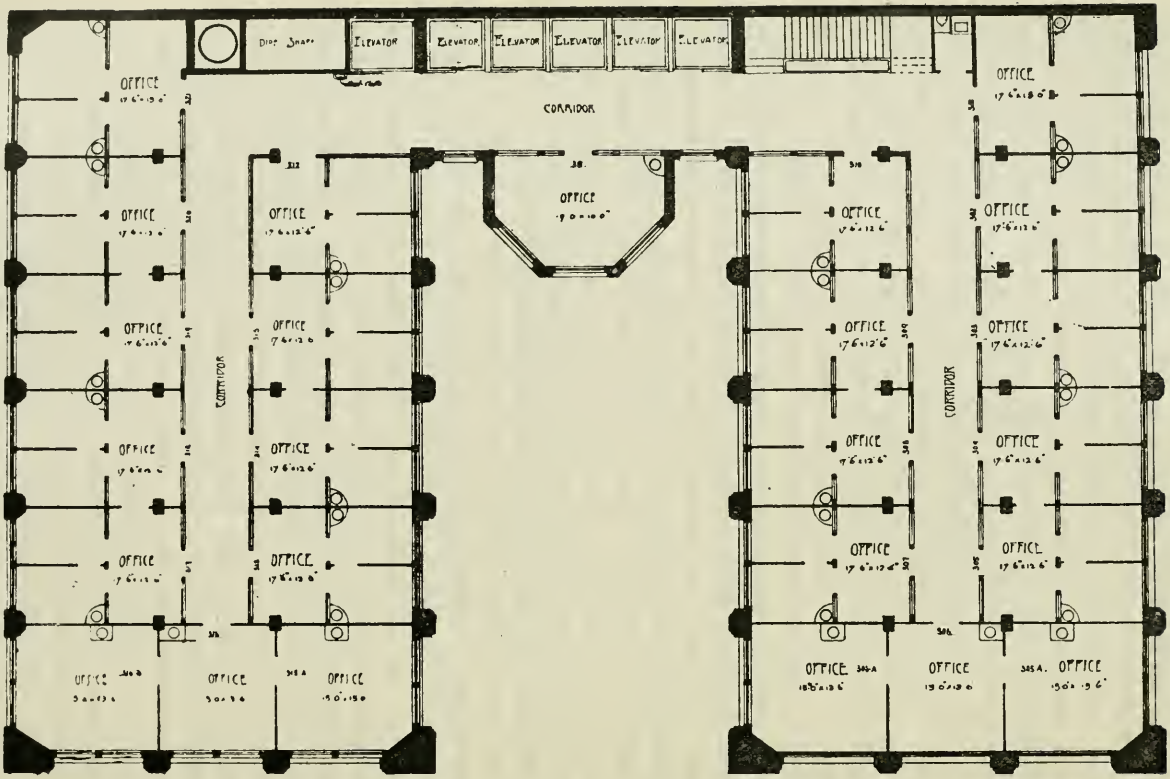
A few years ago 10 or 12 stories were considered formidable attitudes for office buildings; to-day 17, 18, 20 and even more stories are talked of and built as a matter of fact and as scarcely out of the ordinary run. And not only are these buildings high, but they are relatively narrow. This is true more particularly of New York than of Philadelphia or Chicago, in both of which cities, and especially in Chicago, many of the large office buildings are on sites of generous size, to the great dignity of the design, and to the very considerable lessening of the difficulties of the architect. In New York the custom of selling land in lots of 25 feet by 100 has given many of the office buildings an especially unhappy dimension in width, which has rendered a pleasing design a matter of much difficulty for the architect, and which has, in many cases, caused many disastrous results. New York has no such monumental office buildings as the Masonic Temple, the Woman's Temple, the Auditorium, the Schiller Theatre, the Monadnock Block, the Marquette and Old Colony Buildings, and many others in Chicago.

The height is, therefore, the leading element in the structure of the modern office building. Each additional floor adds to its value, and to its natural upward tendency. The vertical element is thus the leading factor in its design, and the architect who most successfully employs this feature achieves a real success in the handling of this very difficult problem; for it is a difficult problem to solve. The historic styles, save the Gothic, are concerned with low or horizontal designs. History and precedent offer little to the designer of the high building, which is at once the most modern of buildings, and an entirely new thing under the sun in architecture. And although modern architecture offers nothing in sequence with the older architecture, save in point of time, it is a task of no small magnitude to break away wholly from tradition and design in a new way for a new purpose. This, however, is just what the architect of the high building has to do, and the speedier this is admitted, the better it will be for the appearance of our streets and the progress of our architecture.

The first problem the architect has to study in his design is the plan. His site must be advantageously used, and his interior disposed so as to secure the most economical use of space, and thus the utmost financial return to his client. The economising of space led to the introduction of the skeleton system, and the necessity of keeping this in mind follows the architect at every step of his work. The first requirement is that every office shall be well lighted; and as every office building is of considerable depth, it is necessary to arrange properly disposed courts. An early method was a central court, with offices opening into it. This is not unobjectionable where the site is large enough to permit a court of good size, and the building is not of too great height. These conditions are admirably fulfilled in the Metropolitan Building in New York, where a spacious interior court, lined with white enamelled brick, affords as much light to the interior offices as the rooms on the street receive on the exterior of the building. The Masonic Temple in Chicago has also a central court, but here it is most unsatisfactory; the building is enormously high, and the court is roofed at the top, so that artificial light must be burned in the interior rooms throughout the day.

A more rational plan is an exterior court, which may be made part of the design of the façade, or may open at the back, and be there connected with similar courts in buildings on the adjoining lots. The Union Trust Company's Building in St. Louis is a good example of the former, and the Wainwright Building, in the same city, and the Stock Exchange and the Marquette Buildings in Chicago, of the second. It has, indeed, been argued that the courts of a high building should always open to the south; but experience will show that they should open on the largest space, no matter what may be the direction of the sun. When the court is behind the façade the design then becomes the treatment of the enclosing wall, and the front does not differ from that of a building with a central court. When it is on the main street it is the leading feature of the design.

The disposition of the courts settled, the arrangement of the offices, the location of the elevators, the size and position

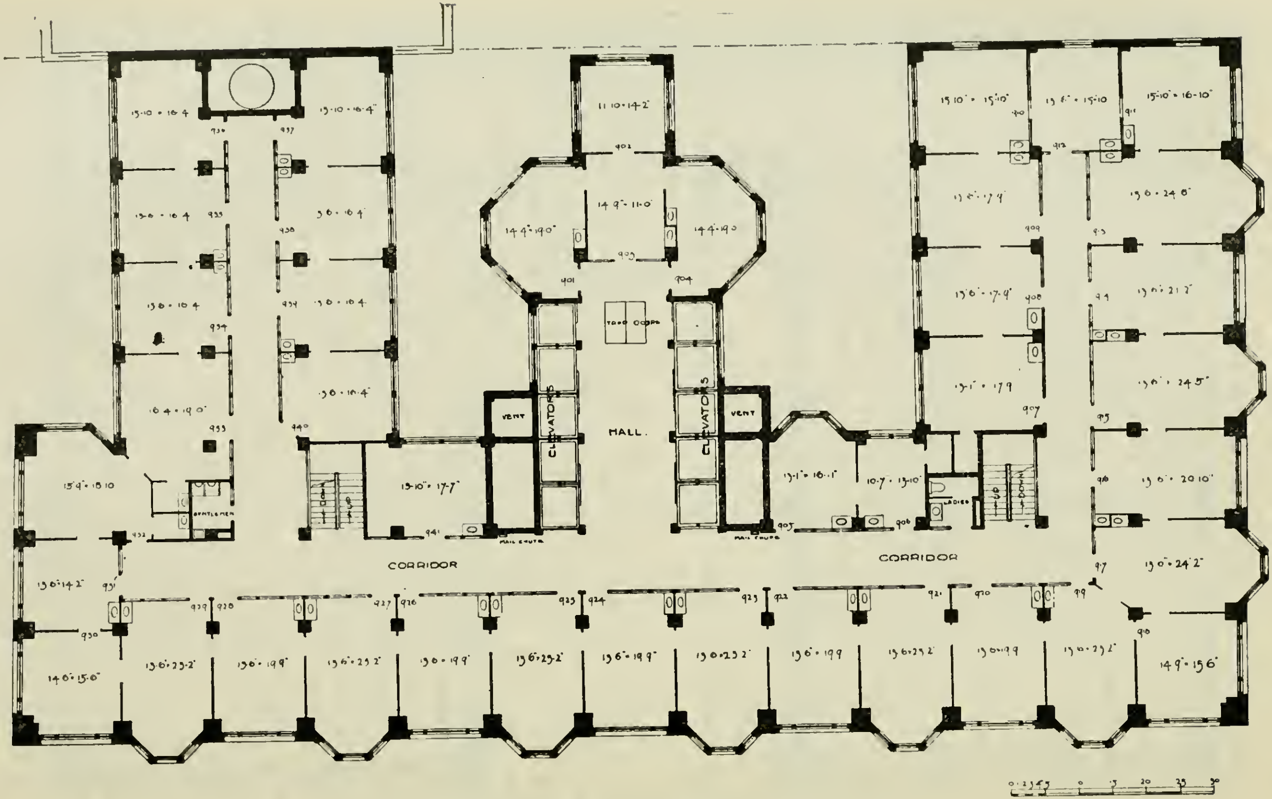


Typical floor plan, Union Trust Building, St. Louis.

of the windows, as well as the position of the columns of the frame, must all be carefully thought out and placed, before the final architectural expression is begun. The situation of the elevators is usually without any influence upon the architecture of the fronts, save as determining the location of the entrances; but all the other elements have a natural and right part to take in the final task.

Every architectural design must have a beginning, a middle and an end. It certainly must begin, and the very highest of high buildings as certainly comes to an end; the space between forms the center. Translating these obvious conditions into architectural language, the front naturally falls into base, superstructure and frieze, in which each part has a logical and necessary function, the base as the beginning, the frieze as the ending, and the superstructure as the main portion between the others; for the base and the frieze cannot, either singly or together, form more than a small portion of the whole. A writer who would consume most of his space in beginning his essay, or in composing his peroration, would seem to have very little to say; so an architect who uses up his façade in getting his building started, or in bringing it to a conclusion would, build he ever so high, have, at the end, produced a minimum of building.

In speaking generally, it is, of course, impossible to lay down rules to be followed in every case. We cannot say that a base should consume so many stories, the superstructure so many and the frieze the balance. The heights of our buildings are too varied, the nature of architectural work too free, to be limited by such arbitrary regulations. But it should be remarked that the general practice in New York is towards high basements, and in Chicago and the West towards relatively low ones. That the latter are the more logical can scarce be argued; for the base is only the beginning of a building, and its function is only that of supporting the superstructure, which, as logically, must be the main portion of the design. An exaggerated basement is, therefore, something to be avoided as unnecessary and unwise. Nor does the frieze need to be stretched out over the



Typical floor plan, Stock Exchange Building, Chicago.

upper part. If practice shows, as it does in many buildings, that the uppermost story is needed for mechanical purposes, and is filled with tanks, piping and apparatus used in heating, lighting and ventilating, this difference of function may be naturally shown in the frieze, whose difference in design not only expresses this fact, but serves, at the same time, as the crown and finish of the building.

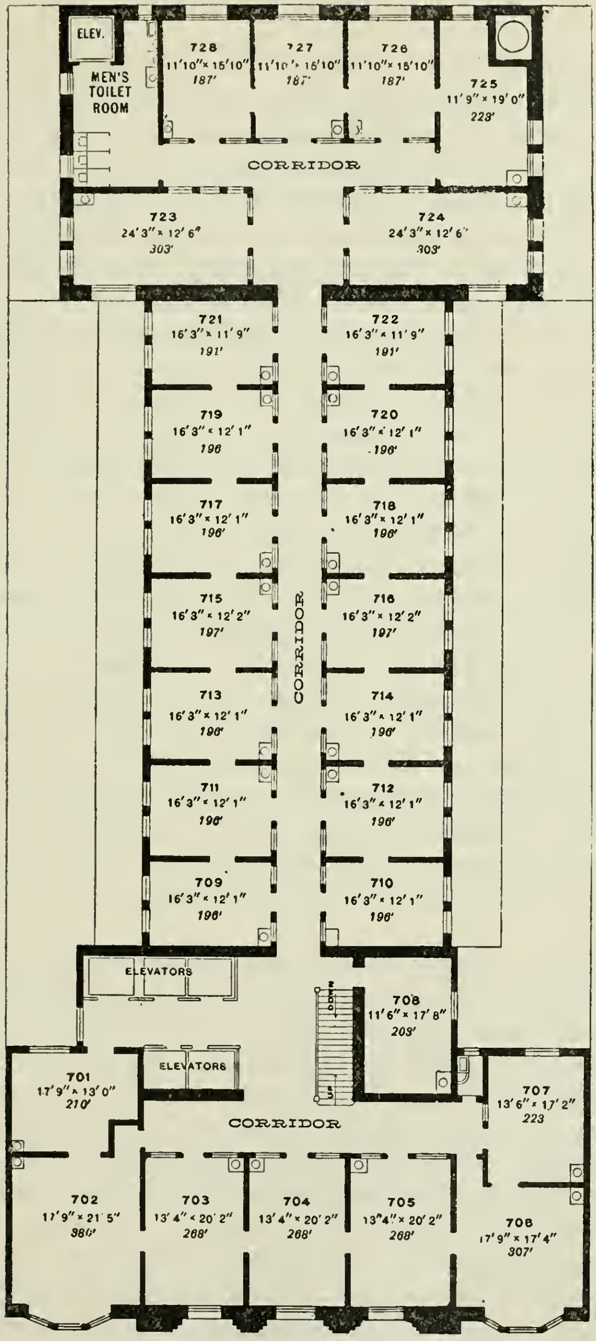
We have, therefore, three great divisions in a high design, each having a function of its own to express, and each having a logical meaning. But these three parts must form a unit. An office building is not a collection of various things put together in a single structure—though many of them offer a most singular diversity of parts—but it is a unit. The basement must be related to the superstructure, and the superstructure to the frieze, and each, in turn, to each other part. The high building must, moreover, be stately and dignified—majestic if it can be, as all great objects are in nature. This effect, which is surely the chief one to be sought in the design of these structures, cannot be obtained through variety, or by cutting up the front into as many parts as possible, only to be arranged and fastened together by means of an internal skeleton of steel. But just as every part of the frame has a meaning, so must every part of the façade. The structure of the office building is an orderly creation, and its architectural or ornamental features must not violate this fundamental law.

Such is the basis on which all good high design must be constructed. Dignity, unity, sobriety, strength, truth ; an expression of parts, an indication of function, a simple, straight forward use of materials employed in the telling of a simple story. We cannot, in our façades, show the number of offices housed within, any more than we can show the diversified interests that make the building their home ; but we can at least keep within the bounds of reason, and proceed with our architectural part as deliberately, as soberly, and as logically as we proceed with the structure of our frame. This, indeed, must be admitted and understood by the architect, or his design will be marred by those misunderstandings that have already fatally injured the beauty of many high office buildings.

The Schiller Theatre in Chicago is a building 80 feet wide and 17 stories high; the depth of the lot is 180 feet. The theatre is on the first floor at the back, the front of the building, and all the upper part over the theatre, being given up to offices. It might as well be called an office building in which the theatre uses part of the space, as a theatre associated with offices. The union of the two buildings in a single structure is an excellent arrangement commercially, since the theatre can occupy a costly site in the heart of the business center of the city, and the owners derive a handsome income from the offices. The same idea lies at the basis of the design of the Auditorium in Chicago, which is a vast opera house surrounded by a business block and hotel, the income from the latter portions being applied to make up any deficiency in the expenses of the former.

The site of the Schiller Theatre being a long rectangle, with the shorter side facing the street, the architects solved the question of courts by narrowing the building at the sides in the center. The theatre fills all the space, except for a line of offices on the street front, up to the fifth floor. At the sixth floor the side walls are dropped in the center, and windows inserted to light the offices on each side of the corridor in the middle of the building. At the back the *scène* runs up above the ceiling of the theatre, but with the seventh floor the whole of the space is given up to offices, front, back and sides, the plan resembling a gigantic **I**. At the ninth floor the front is stopped on each side, to permit free access of light to the side courts within, the main portion being continued to the seventeenth floor, and given the architectural form of a tower.

The treatment of the front is masterly, and has, perhaps, never been surpassed in high design for simplicity and directness of expression, at once structural and beautiful. The tower in the center is divided into three great bays, finished with round arches at the top, and enclosing spacious and plain windows. At the top is a frieze story of small, round, arched windows, in a rich frame of foliated ornament, that is continued on the broad, boldly projecting cornice which completes the design. The treatment of the

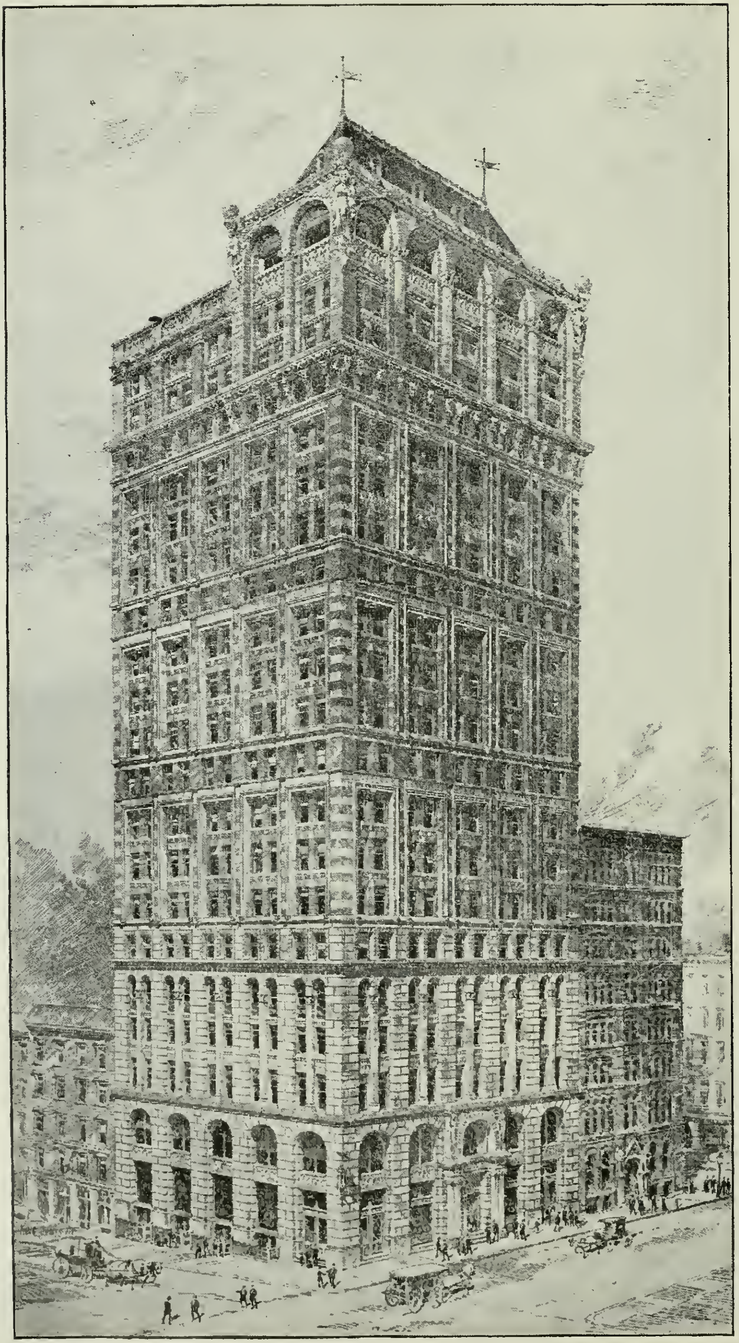


Plan of seventh floor, Schiller Theatre, Chicago.

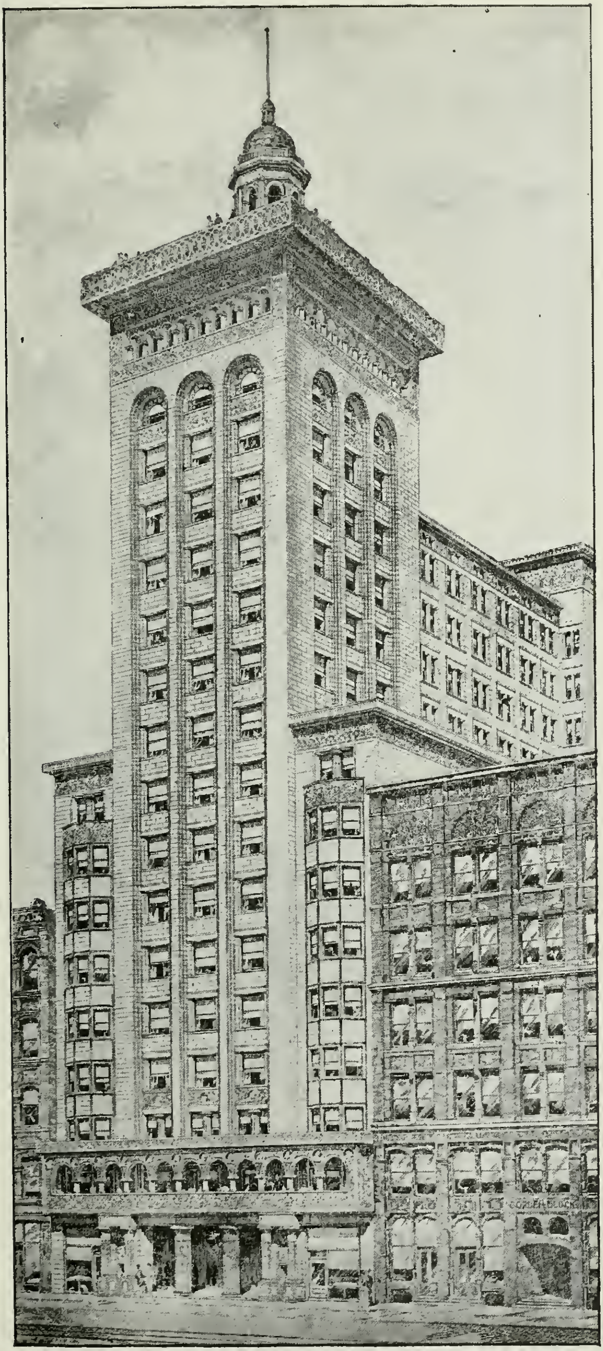
wings is equally fine; a simple bow window stopped below the uppermost story and a richly decorated frieze and cornice to correspond with the treatment of the center.

Now, the theatre is an essential part of this building; it is natural and fitting, therefore, that it be expressed in the design. This has been done in an exceedingly happy manner, by carrying a richly-carved balcony across the front of the building at the second floor, and by surmounting the tower with an open belvedere, which is not, it is true, visible from the street directly in face, but is nevertheless an integral part of the design. The balcony would be an anomaly in a strictly commercial design, but here it has a natural function in setting the building apart, as it were, from strictly commercial buildings. We have, therefore, a very great artistic success. The building has a beginning, a middle and an end; its design is structural, for the great vertical lines correspond to the columns of the frame which are contained within the facing piers; the window space is ample and sufficient; the plan is employed in a natural manner as an important element of the design; the festal nature of the structure is sufficiently indicated in the ornamental balcony and belvedere; finally, the whole has been carried out with a consummate artistic feeling and appreciation of the problem, which is not only rare to find in works so utilitarian as this, but which we often look for in vain in structures of a purely artistic and ornamental nature.

Among the many notable commercial buildings illustrating the same principles of design by the same architects, I shall only have space to refer, in the briefest manner, to the Guaranty Building, at Buffalo. This is a 14-story, rectangular building, on an ample site. The basement is of 3 stories, the superstructure of 10, the frieze of 1. The leading element of the superstructure is the vertical lines of the piers between the windows, which, at the thirteenth floor, are connected by small, round arches, and, in design, are joined with the circular windows of the frieze. The whole of the surface of this building is covered with ornament; not structural ornament, as columns and pedi-



American Tract Society's Building, New York.



The Schiller Theatre, Chicago.

ments, and other artificial additions, but a finely designed, carefully modelled surface ornament, very rich in detail, yet kept well within the structural lines of the architecture. Though possibly the most richly decorated commercial building in America, the skill of the artist has produced a design of structural sobriety with great richness of effect.

In both these designs, their success has depended, apart from the artistic feeling displayed in them, upon their unity. And this effect has been obtained, not only by the co-relation of the various parts of the façades to each other, but particularly by the long vertical lines of the superstructure, which naturally express the columns of the frame. That unity can only be obtained in a high design by unbroken vertical lines, is apparent in comparing either of Mr. Sullivan's buildings with one in which the horizontal lines predominate. The building of the American Tract Society, in New York, is a fair example of such a structure.

It is true, the design of the Tract Society's building is not devoid of some eccentricity; but as it is one of the highest and latest office buildings in New York, and reflects, moreover, the average principles of office design in that city, it may not unfairly be taken as a type of New York commercial design.

The building is a rectangle, with a small open court on the inner side adjoining the entrance front. Unlike many New York office buildings, the site is spacious, though its tremendous height of 23 stories has added to its apparent altitude. The most striking thing in this design is not its unity, but its diversity. We know it is a steel skeleton building, because no structure of this height would have been built on a site of this size in any other way; and, while there are no voids over solids, or solids over voids, there are no continuous vertical lines for a greater height than 3 stories in any part of the façades. The design, in fact, is not a single, homogeneous one, in which one part naturally develops into the other and each is related to the other, but instead, we have six great divisions piled one on top of each other, of independent design and without any relationship to any other part.

At the beginning we have a basement of 2 stories, and, as every building must have a base, this entirely fulfils the requirements of good design. But above this comes a three-story section which is not a basement, because it is cut off from the part below by a cornice, and is, moreover, 2 stories above the level of the street; nor can it be a superstructure, for the major part of the building is above it. It is impossible to give it a proper architectural name, though as it is of stone, like the two stories below, and the upper part of the building is of terra-cotta, it may, in the mind of its designer, have formed part of the basement. Over the cornice of this section is another section—a single story that appears to be an introduction to what is above it; then 3 stories with the windows enclosed within rectangular bays. A narrow string course runs below and above this part, and over it the same features are repeated; that is, the introductory story and the 3 stories in bays. And over this again they are repeated once more, cut off, as below, with horizontal lines, and forming sections complete in themselves. Over this is the heavy main cornice, supported on large brackets which entirely fill the space between the windows of another story. Here the building logically ends, for the cornice is naturally the finish of a building. But we have not yet reached the end, for above are more stories, with a great, porch-like erection in front, of applied columns carrying round arches, which are open and form a sort of belvedere; within these rises the hipped roof, which has a singular effect of growing out of the space behind the arches.

The error that led the designer of this building astray is very obvious; he did not understand the value of unity in a high building, and certainly did not know how to obtain it. Instead of unity, sobriety and strength, we have variety and change. The design is varied at every possible point, and cut up by horizontal lines and divided into shallow sections, in the false hope of making the building seem lower than it is. Yet it is part of its merits in the eyes of its owners that it is big; why, then, disguise this fact? And why, if it is a single building, and therefore a unit, mar its unity by cutting it into parts, and varying its design for sheer sake of variety? The porch on the top is most unhappy in its effect: it completes the building, but only because there is nothing above it; it certainly is without relationship to what is below, nor are any of the lower sections related to any other part. There is ample material here for a good design; the architect has brought to his work a broad acquaintance with his art, and a fine mastery of detail, but he did not understand his problem. There is no structural significance in the design—simply a using up of space, and an evident fear of long, uninterrupted lines.

It would be easy to multiply examples of badly conceived designs for office buildings, or to name buildings that violate the rules of art more flagrantly than the one we have just studied, but this must suffice. It is folly to deny that the average artistic standard of design in the modern office building is not good. The "sky-scraper" has become a synonym for things of horror, and a blot upon the artistic aspects of our modern cities. That they are so is frequently true, but the error lies in the treatment, not in the dimensions of the buildings. Great office buildings like the Schiller Theatre, the Stock Exchange, the Auditorium, the Old Colony Building, the Monadnock Block and others, in Chicago; the Wainwright and the Union Trust, in St. Louis; the Mills Building, in San Francisco; the Guaranty Building, in Buffalo; the Union Trust Building, in New York; the Ames Building, in Boston, and some few others in these and other cities, show that, logically and artistically treated, the modern office buildings may be ornaments to our cities, and, by virtue of their art alone, take that supremacy to which, in the popular mind, they are entitled by reason of their size and their cost.

The last few years have witnessed a prodigious growth in the number of office buildings in the large cities of the United States. The architects have been eager to build them, for such costly work gives them more profitable employment than much of the lesser work they are usually engaged upon. They have become popular with investors; they have been used as an advertisement in displaying the wealth of their owners; they have become an integral part of our modern commercial life. But their artistic progress has not kept pace with their structural development. The solution of the façade is not, indeed, yet to be found, for the vertical designs of many of the Western office buildings show the system to be followed in all high buildings, but the façade calls for a more rational treatment than has yet been given it in the larger number of instances. The duty of the architect, so far as artistic effect is concerned, is chiefly limited to the façade. The interior of the office building offers little to the visitor or the tenant in the way of artistic enjoyment. Well-lighted offices, ample elevator service, light corridors, convenient toilets, and abundance of sunlight, the best of ventilation, and a satisfactory system of heating and plumbing, are what the tenant requires more than decorated apartments. In buildings devoted, in part, to great corporations, the rooms of the company, as in the Manhattan and the Metropolitan Buildings, in New York, will be fitted up in a sumptuous fashion, regardless of expense. But these are private apartments, and form no part of the public features of the buildings. The entrance halls and elevator enclosures thus remain as almost the sole parts of the interior susceptible to artistic treatment. The value of a rich decoration for these parts has long been admitted by the architects and owners, and many splendidly decorated halls have been built in the larger office buildings.

The most notable of these is, without doubt, the interior court of the Metropolitan Building in New York, a superb apartment, lined with decorated marble, with delicate carving, with onyx and with bronze, with a disregard of cost and a sumptuousness of effect that is comparable only to the palatial architecture of Europe. That large expenditures are made for such decorative work as this speaks much for the general appreciation of art in the modern office building, and certainly the history of architecture offers few more striking contrasts than that between a palatial structure like the Metropolitan Building and the little 4- or 5-story buildings in which the merchants of a generation or less since transacted their business, and laid the foundations of the fortunes that, to-day, render our vast office buildings possible and profitable.

ACIDIMETRIC ESTIMATION OF VEGETABLE ALKALOIDS. A STUDY OF INDICATORS.*

By Lyman F. Kebler.

In volumetric analysis, the first question demanding attention is a suitable indicator or delicate end-reaction. The writer's object in this communication is to present the results of a study of five indicators in titrating alkaloids, in the hope that it may be of some service in formulating systematised methods of analysis in alkaloidal chemistry. The discordant analytical results often obtained by different chemists operating on the same sample are greatly to be regretted. It is the writer's opinion that the discrepancies are chiefly due to differences in *modus operandi*, to defective apparatus, and, in volumetric analysis, to different end-reaction tints arbitrarily assumed by each worker.

In order to eliminate as completely as possible the factors of uncertainty, the burettes and a pipette were carefully calibrated in order to ascertain the necessary factor for correction. A glass-stoppered cylinder was also standardised. All efforts to standardise a liter flask were thwarted. A large balance sufficiently sensitive to do the work satisfactorily could not be found.

In titration the personal equation plays an important part. Authorities are not agreed on end-reaction tints, each operator relying on his own judgment. The writer thinks it correct to titrate to the point where a different color from the initial color is developed. In this work[1] the writer titrated from acid to alkaline solutions as follows: Brazil wood, from yellow to onion-red, the purple ultimately fading to this; cochineal from yellow to bluish-red; hæmatoxylin from yellow to brown-orange; litmus from red to onion-red, and methyl-orange from red to straw-yellow.

---

* Abstract of a communication read to the Chemical Section, September 17, 1895.

[1] Alkaloids, generally, are neutral to phenolphthalein, consequently it cannot be employed in titrating alkaloids directly. It is available for indirect titrations, *i. e.*, estimating the amount of acids combined with an alkaloid in its neutral salts.—L. F. K.

The indicator solutions were prepared according to the most approved processes. Cochineal and litmus, according to the specifications of Sutton's Volumetric Analysis, sixth edition. Phenolphthalein, 1 gram dissolved in 1 liter of 50 per cent. alcohol. Hæmatoxylin, well crystallised, 1 gram dissolved in 100 c.c. of strong alcohol. The method best suited for preparing the Brazil wood solution, is to place 3 grams of the wood into a casserole, add 10 c.c. of distilled water, boil gently for a few minutes, cool, and filter. A freshly prepared solution has given the writer the most satisfactory results. Methyl-orange, 1 gram dissolved in 1 liter of distilled water. Considerable difficulty was experienced in obtaining even a fairly satisfactory product of methyl orange. Reinitzer's[2] method for preparing the litmus solution did not come to the writer's notice until considerable work had been done with the solution prepared as above.

In titration, the following quantities of the several indicators were employed: methyl orange, Brazil wood, cochineal, and phenolphthalein, 5 drops each; litmus, 10 drops, and hæmatoxylin, 3 drops.

The standard solution, from which the exact strength of the other volumetric solution was determined, was a solution of normal sulphuric acid. This was prepared from data obtained by the several methods; titration against pure anhydrous sodium carbonate, using the above indicators; by precipitation as barium sulphate, and by Weinig's[3] process. The last method is simple, and gave the most satisfactory results. The following are the data obtained from an approximately normal sulphuric acid solution with the above methods:

---

[2] *1894, Ztschr. angew. Chem.*, 547, 573; *Chem. News*, **70**, 225, 239, 249.
[3] 1892, *Ztschr. angew. Chem.*, 204; *Analyst*, **17**, 99.

Indicators, and Methods.	*No. of c.c. of Acid Solution required per 10 c.c. of Normal Sodium Carbonate.*	*Grams of SO_3 in 10 c.c. of the Acid Solution.*
Brazil wood	9·50	0·4211
Hæmatoxylin	9·54	0·4192
Cochineal	9·50	0·4211
Litmus	9·50	0·4211
Methyl orange	9·50	0·4211
Phenolphthalein	9·45	0·4216
Weinig's method	—	0·4247
Barium sulphate method	—	0·4200

Due precaution was taken to boil the solution thoroughly with the indicators requiring it. With solutions of the above strength it was impossible to detect any difference in the sensitiveness of most of the indicators.

With the normal sulphuric acid solution, a normal solution of pure potassium hydroxide was standardised. From the normal sulphuric acid solution and normal alkaline solution there were prepared, respectively, a decinormal acid solution and a centinormal alkaline solution. The two solutions thus prepared were carefully titrated against each other, employing the above indicators, with the following results:

Indicators.	*No. of c.c. of Normal Sulphuric Acid.*	*No. of c.c of Centinormal KOH Required per 10 c.c. of Decinormal H_2SO_4.*	
		La Wall.	*Kebler.*
Phenolphthalein	10	101·80	102·00
Brazil wood	10	99·56	100·00
Cochineal	10	100·58	99·80
Hæmatoxylin	10	99·76	100·00
Litmus	10	99·97	99·60
Methyl orange	10	92·67	98·53

My associate, Mr. LaWall, took up a portion of the work independently, using the same solutions and apparatus. The above and all subsequent results are the average of duplicate, triplicate, or more titrations.

The titration of pure alkaloids, as found in the market, was next undertaken. With quinine and codeine the following method was used: 2 grams of the alkaloid were placed in the cylinder, dissolved in alcohol, and diluted with alcohol to 100 cubic centimeters. To 10 cubic centimeters of this solution and the requisite quantity of indicator contained in a suitable beaker, the decinormal acid solution was added to slight excess, agitated, allowed to stand a few minutes, the sides of the beaker well washed down with distilled water, adding about 40 cubic centimeters, and the excess of acid titrated back with the centinormal alkaline solution.

With alkaloids not freely soluble in alcohol, the following procedure was adopted: 2 grams of the alkaloid were placed into a 200 cubic centimeter beaker, 75 cubic centimeters of decinormal acid added, the contents of the beaker warmed on a water bath, and occasionally agitated until the alkaloid was dissolved. The beaker and contents were then cooled, the contents transferred to a 100 cubic centimeter cylinder, the beaker carefully rinsed with several successive portions of water, transferred to the 100 cubic centimeter cylinder, and finally made up to 100 cubic centimeters with water. Each 10 cubic centimeters contained ·2 gram of alkaloid and 7·5 cubic centimeters of decinormal acid solution. After adding the requisite amount of indicator to 10 cubic centimeters of the alkaloidal solution, and diluting up to about 50 cubic centimeters, the excess of acid was carefully re-titrated. Two or more titrations were made in every case, with the same solution and indicator, by adding to the solution just finished another portion of the decinormal acid solution, and re-titrating with the centinormal alkaline solution, taking finally the average reading.

With quinine, strychnine, morphine and codeine, the following results were obtained:

	Quinine.		*Strychnine.*	*Morphine.*	*Codeine.*
Indicators.	*La Wall.*	*Kebler.*	*Kebler.*	*Kebler.*	*Kebler.*
Brazil wood	99·90	101·97	99·36	98·93	95·75
Cochineal	105·56	102·54	103·20	99·08	97·09
Hæmatoxylin	99·81	103·37	100·03	98·17	95·90
Litmus	101·80	103·55	103·54	98·93	96·38
Methyl orange	—	123·27	104·21	100·59	98·11

The analyst has rarely to investigate the purity of refined alkaloids, but the crude alkaloids claim a greater share of his time and attention.

The next step was to investigate the adaptability of the above process to crude morphine and crude cocaine. The results are as follows:

Indicators.	*Crude Morphine.* *La Wall.*	*Crude Morphine.* *Kebler.*	*Crude Cocaine.* *Kebler.*
Brazil wood	99·23	98·47	95·90
Cochineal	100·14	99·53	97·11
Hæmatoxylin	99·08	97·59	95·74
Litmus	99·50	98·93	96·82
Methyl orange	102·10	100·02	100·14

Notwithstanding the fact that crude alkaloids claim considerable attention on the part of the analyst, only a few are found on the market already extracted. It generally happens that the operator is required, not only to determine the amount of pure alkaloids, but also to extract them from their natural sources. For this purpose the writer employed a modification of Keller's process. The method is as follows: Place 10 grams of the dry drug into a 250 cubic centimeter flask, add 25 grams of chloroform, 75 grams of ether, stopper the flask securely, agitate well for several minutes, add 10 grams of 10 per cent. ammonia water, then agitate frequently and during one hour. On adding 5 grams more of 10 per cent. ammonia water and shaking well, the suspended powder agglutinates into a lump, the liquid becomes clear after standing a few minutes, and can be poured off almost completely.

(1) When the mixture has completely separated, pour off 50 grams into a beaker, evaporate the solvent on a water bath, add 10 cubic centimeters of ether, and evaporate again. Dissolve the varnish-like residue in 15 cubic centimeters of alcohol, with heat; add water to slight permanent turbidity, the requisite quantity of indicator and an excess of the acid solution; re-titrate with the centinormal alkaline solution.

(2) When the mixture has completely separated, pour 50 grams into a separatory funnel, treat at once with 20 cubic centimeters of acidulated water. After thorough agitation and complete separation, remove the aqueous solution into a second separatory funnel. Repeat the above operation twice more successively with 15 cubic centimeters of slightly acidulated water. The acidulated water in the second

separatory funnel is rendered alkaline with ammonia water, the alkaloid removed successively with 20 cubic centimeters, 15 cubic centimeters and 15 cubic centimeters of a mixture of 3 parts (by volume) of chloroform and 1 part of ether. Collect the chloroform-ether mixture in a tared beaker and distil off the solvent. The varnish-like residue is twice treated with 8 cubic centimeters of ether, evaporated on a water bath and dried to constant weight on the water bath. The varnish-like residue is next dissolved in 15 cubic centimeters of alcohol and treated as in (1) above.

Nux vomica and ipecac root were treated according to processes (1) and (2); belladonna leaves according to process (2). The results are as follows:

	Per Cent. of Alkaloids in Nux Vomica by Process (1).		*Per Cent. of Alkaloids in Nux Vomica by Process (2). Gravimetrically.*		*Per Cent. of Alkaloids in Nux Vomica by Process (2). Volumetrically.*		*Per cent of Alkaloid in Ipecac Root by Process (1).*	
	La Wall.	*Kebler.*	*La Wall.*	*Kebler.*	*La Wall.*	*Kebler.*	*La Wall.*	*Kebler.*
Brazil wood . .	2·04	2·58	2·94	3·00	2·37	2·37	2·46	2·54
Cochineal . . .	2·64	2·69	2·86	3·10	2·42	2·39	2·59	2·49
Hæmatoxylin .	2·18	2·24	2·88	3·11	2·23	2·27	2·48	2·54
Litmus	2·38	2·34	2·93	3·05	2·55	2·37	2·55	2·57
Methyl orange .	3·02	3·64	2·93	3·02	2·65	2·61	2·95	3·30

	Per Cent. of Alkaloid in Ipecac Root by Process (2). Gravimetrically.		*Per Cent. of Alkaloid in Ipecac Root by Process (2). Volumetrically.*		*Per Cent. of Alkaloids in Belladonna Leaves by Process (2). Gravimetrically.*		*Per Cent. of Alkaloids in Belladonna Leaves by Process (2) Volumetrically.*	
	La Wall.	*Kebler.*	*La Wall.*	*Kebler.*	*La Wall.*	*Kebler.*	*La Wall.*	*Kebler.*
Brazil wood . .	2·58	2·60	2·36	2·35	0·26	0·20	0·19	0·15
Cochineal . . .	2·63	2·68	2·52	2·33	0·28	0·20	0·24	0·14
Hæmatoxylin .	2·58	2·68	2·35	2·33	0·27	0·22	0·21	0·13
Litmus	2·62	2·60	2·40	2·25	0·24	0·18	0·20	0·15
Methyl orange .	2·66	2·63	2·89	2·61	0·25	0·20	0·23	0·20

From the foregoing results it may safely be concluded that methyl orange cannot be numbered with the indicators suitable for titrating alkaloids. With centinormal, fifth decinormal and other solutions of various strengths, it fails to give satisfactory results. Notwithstanding the sensitiveness claimed for it, the writer believes that its days, as an ideal indicator, are numbered. Even Professor Lunge, the staunch advocate of methyl orange, has admitted that a properly prepared solution of litmus is superior to this indicator, in inorganic estimations.

Of the indicators thus far considered, hæmatoxylin, Brazil wood, and cochineal give very promising results. Hæmatoxylin is properly entitled to the first place, and Brazil wood to the second. Other indicators will be considered in due time.

THE MORE VALUABLE LITERATURE ON INDICATORS DURING THE LAST TWO DECADES.

1877, E. Luck, *Ztschr. anal. Chem.*, **16**, 332.

1880, A. Baeyer, *Ann. Chem.* (Liebig), **202**, 68.

1881, R. B. Warder, *Am. Chem. J.*, **3**, 55.

1882, G. Tobias, *Ber. d. chem. Ges.*, **15**, 2452.

1883, R. T. Thomson, *Proc. Phil. Soc.*, Glasgow, **14**, 156, 173; *Chem. News*, **47**, 123, 135, 184.

1883, H. Beckurts, *Pharm. Centralhalle*, **24**, 333; Abstr., *Ber. d. chem. Ges.*, **17**, 3073.

1883, J. Wieland, *Ber. d. chem. Ges.*, **16**, 1989.

1883, R. T. Thomson, *Proc. Phil. Soc.*, Glasgow, **15**, 63, 194; (1884), *Chem. News*, **49**, 32, 38, 119.

1884, H. Beckurts, *Pharm. Centralhalle*, **25**, 101; Abstr., *Ber. d. chem. Ges.*, **17**, 238.

1884, C. Kraemer, *Ber. d. chem. Ges.*, **17**, 1875.

1884, F. A. Flückiger, *Arch. d. Pharm.*, (3), **22**, 605.

1885, G. Lunge, *Ber. d. chem. Ges.*, **18**, 3290.

1885, R. T. Thomson, *Chem. News*, **52**, 18, 29.

1885, M. Berthelot, *Comp. rend.*, **100**, 207; Abstr., *Ber. d. chem. Ges.*, **18**, 93.

1885, M. C. Traub, *Arch. d. Pharm.* (3), **23**, 27; Abstr., *Ber. d. chem. Ges.*, **18**, 126.

1885, M. Dechan, *Pharm. J. Trans.* (3), **15**, 849.

1885, J. H. Long, *Chem. News*, **51**, 160.

1885, H. N. Draper, *Chem. News*, **51**, 206.

1885, R. Engle and J. Ville, *Bull. Soc. Chim.*, **44**, 17.

1885, B. Fischer and O. Philipp, *Arch. d. Pharm.* (3), **23**, 434; Abstr., *Ber. d. chem. Ges.*, **18**, 583.

1885, T. Lehmann and J. Petri, *Arch. d. Pharm.* (3), **23**, 243; Abstr., *Ber. d. chem. Ges.*, **18**, 625.

1889, J. H. Long, *Am. Chem. J.*, **11**, 84.

1891, A. H. Allen, *Analyst*, **17**, 186, 215.

1891, G. Lunge, *J. Soc. Chem. Ind.*, **10**, 314.

1891, J. Lüttke, *Apoth. Ztg.*, **7**, 643; *Ztschr. anal. Chem.*, **31**, 692.

1893, M. B. Breed, *J. Frank. Inst.*, **135**, 312; *J. Anal. Appl. Chem.*, **7**, 204.

1893, R. T. Thomson, *J. Soc. Chem. Ind.*, **12**, 432.

1894, B. Reinitzer, *Ztschr. angew. Chem.*, 547, 573; *Chem. News*, **70**, 225, 239, 249.

1894, G. Lunge, *Ztschr. angew. Chem.*, 733.

1894, W. Schafer, *Apoth. Ztg.*, **9**, 839; Abstr. *Analyst*, **20**, 37, (1895).

NOTES AND COMMENTS.*

ANNUAL REVIEW OF SCIENCE AND INDUSTRY.†

Iron and Steel.—After two years of almost continuous decline in output and prices, culminating, about the middle of 1894, in profound depression, the iron and steel trades of the United States began to exhibit signs of recovery, which, towards the middle of the year, assumed the proportions of a veritable "boom," both prices and production advancing at an unprecedented rate. The improvement noted, while affecting all branches, was most marked in the steel trade. In September, the production of pig iron was at the rate of 10,500,000 tons, the highest point ever reached. In November, it had reached the rate of 11,500,000 tons, which was maintained substantially to the close of the year. The steel trade has met with somewhat of a check; but as regards manufactured products—bar iron, structural forms, etc.—the greater portion of the improvement made earlier in the year was maintained at the close.

A conspicuous feature of the trade, which has been emphasised by the events of the past two years, is the rapid extension of the demand for iron and steel for various structural uses, and the relative decrease of the demand for railroad uses. The railroads, which, until recently, were the greatest consumers of steel, in the recent developments of the trade, have been relegated to a subordinate position; partly, it may be explained, on account of the business depression which the railroads have felt most severely; but partly, also, because of the actual growth in the uses of steel for building and other miscellaneous purposes.

The falling off in the consumption of rails is explained by the figures of new railroad construction, which declined, in 1895, to the lowest point for thirty years. The most reliable authority gives the new mileage of 1895 as 1,300 miles, as compared with 1,760 miles reported in 1894. The severe economies which the railroads were compelled to put in practice, and which reduced the demands for repairs and renewals of permanent way and rolling stock to the lowest figures, have also had their share in lessening the consumption from this source.

It is yet too early to give with accuracy the figures of production of iron‡ and steel, but it is safe to say that, in the items of pig iron and ingot steel, they will be found to have equalled the best previous record. With the return of business to normal conditions, it needs no special foresight to predict an expansion of these important industries that will eclipse even the remarkable growth of the past decade.

---

* From the Secretary's monthly reports.

† An abstract of the report of the Secretary to the annual meeting of the Franklin Institute, held January 15, 1896.

‡ Since writing the above, we have observed an estimate of pig iron production, made by the *American Manufacturer*, of Pittsburgh, which confirms the opinion above given. The *Manufacturer's* figures place the pig iron output for 1895 at 9,387,639 tons, which exceed those of 1890 (heretofore the year of heaviest production) by about 185,000 tons.

Gold.—There is every reason to believe that the world has just entered upon a period of enormously increased gold production, which promises not only to rival or even greatly exceed the greatest output of the best days of California and Australia, but which promises also to continue in an increasing ratio for many years to come. The financial and commercial influences of this impending deluge of the precious metal, in the opinion of experts, cannot fail to be profound and far-reaching. The statistics of gold production for the past year exhibit a largely increased yield from all the leading mining regions. The greatest increases, however, are shown by the yield of the Transvaal district in South Africa, and of Colorado in the United States. The greatly increased demand for gold throughout the civilised world, which has stimulated the search for new deposits, and the introduction of improved processes whereby enormous deposits of low-grade ores—heretofore valueless—can be profitably mined, are the chief factors of this most important development. It may be of interest to note, in passing, that, in the past year, the United States once more resumed the first place among the gold-producing countries, which for a time had been held by Australia, while Africa advanced to the second place.

Electric Railways.—Notwithstanding the prevalence of unfortunate business conditions, the extension of the electric railway throughout the country continued without evidence of abatement. It is estimated that the additions to electric lines in the United States in 1895 were not less than 1,800 miles, as compared with 1,500 in 1894. About one-fourth of this may be referred to new railways, and the remainder to the changing from animal to electric traction by existing roads.

A highly important development is the adoption of the electric system of traction by several of the steam railways. The Nantasket Beach branch of the New York, New Haven and Hartford Railroad was operated by electricity during the past year, and the introduction of a 95-ton electric locomotive for the hauling of heavy trains in the Baltimore and Ohio tunnel at Baltimore attracted much comment. The success which has attended these experiments has given rise to an unusual amount of discussion respecting the future possibilities of electricity in railroad work. A significant circumstance in connection with this phase of the subject is the reported combination of the interests of the Westinghouse and Baldwin Companies for the manufacture of electric locomotives.

The most important item in this field was the completion and opening for public service of the elevated electric railway system in Chicago, referred to in my last year's review. The system of under-surface or conduit traction for electric railways, also has been brought into prominence by the results of experiments, during the past year, on the Lenox Avenue road in New York, and by the successful operation of the Connett-Budapest system in Washington. The outcome of the New York experiment is the official announcement that this or a similar system will shortly be adopted by all the important surface roads in that city; and, speaking in general terms, the experience gained in these trials appears to have demonstrated that the difficulties involved in under-surface electric traction have been greatly overestimated.

Electric Power Transmission.—The most interesting event in the electric field that occurred during the past year was the starting of the great Niagara Falls Power Plant, which has been the subject of numberless articles in the technical press of the world. It will be unnecessary to make further reference to this subject here, save to say that the carefully made plans of the engineers in charge of the work, prominent among whom was, and is, Dr. Sellers, the distinguished professor of mechanics in this Institute, appear to have proved highly successful. The large turbines and generators are now delivering current to a number of manufactories established on the ground, and the extension of the transmission to Buffalo—twenty-two miles distant—awaits only the settlement of the terms of contract. The successful demonstration at Niagara will, no doubt, give the needful stimulus for the erection of power transmission plants in numerous other localities, favorably situated in respect of water powers. Several projects of this character now under consideration were referred to in last year's review.

Electro-Metallurgy.—During the past year great interest was aroused by the announcement that Mr. Thomas L. Willson had developed an electric furnace process adapted for the production on the commercial scale of calcium carbide. The special interest attaching to this announcement grows out of the fact that calcium carbide furnishes a source from which acetylene gas may be obtained by simple interaction with water. Acetylene gas possesses extraordinary illuminating qualities, and the promoters of Mr. Willson's patented inventions bearing on the subject have declared that they are able to manufacture the carbide at a cost sufficiently low to place acetylene gas upon the market as a competitor of other illuminating systems. The actual demonstration of this claim would unquestionably be followed by extensive and decided changes in the field of illumination. For the present, however, it would be safest to suspend judgment on the question and to await developments, especially since, on this all-important question of cost of producing the raw material there exists among experts the widest diversity of opinion, and theory based on thermo-chemical considerations affords us no trustworthy ground upon which to base estimates of output.

When the conditions which prevail in the electric furnace are as well understood as those of our well-known metallurgical furnaces, many problems, now obscure, will be satisfactorily solved, and we shall have tenable ground to stand upon in making predictions based on relations between the heats of formation of the novel compounds formed in the electric furnace and the energy consumed. Thus far, however, the controlling data needful for the understanding of the reactions that take place under these circumstances are wanting.

It would be highly imprudent, however, to ignore the fact that the probabilities are all in favor of a better understanding, and more perfect control of this new and remarkable adjunct in metallurgical operations, and that the immediate future may witness advances of an astonishing nature in electric furnace methods and results.

In the *electrolytic branch of electro-metallurgy* the progress of the past year has been rather in the direction of extension and improvement of methods than in new discovery.

The aluminum industry has been greatly stimulated by the starting of the new works of the Pittsburgh Reduction Company at Niagara, and by the enlargement of the works of the Neuhausen Company in Switzerland. These and other enlargements of existing works have greatly increased productive capacity, the immediate effect of which has been a reduction in the selling price of the metal, and this in turn must have, as its natural outcome, the finding of new uses for it. It is not unlikely, from present indications, that we may have aluminum selling at 25 cents a pound within a short time. There is nothing that could illustrate more strikingly than the history of the aluminum industry the rapid and substantial advance of electro-metallurgical methods. But little more than ten years ago, aluminum was selling at $10 per pound, and the consumption was about 5,000 pounds per year. At present it can be had for 35 cents per pound, and the consumption is at the rate of more than 1,000 tons per year, and is rapidly growing.

The establishment at Niagara of a large plant for the manufacture of the new abrasive material—carborundum—an electric furnace product, is a circumstance worthy of note. This product has some highly interesting properties, and appears to have firmly established its reputation as a valuable addition to the list of abrading substances known in the arts.

The *chemical industry* has also been the gainer by the successful introduction, in England, of a process devised by Mr. H. Y. Castner for the production of caustic and chlorine by the electrolytic decomposition of common salt. The solution of this problem has been sought by a number of inventors ; but until the announcement of Mr. Castner's process and results, the success of the electrolytic methods has been regarded as very doubtful. The results already demonstrated by the improved methods here referred to are extremely promising, and the opinion of experts best qualified to judge of them is highly favorable. Some, indeed, do not hesitate to say that in ten years the electrolytic methods for soda and bleach will have practically supplanted the Leblanc and Solvay processes that now have possession of the field.

It is worthy of notice that arrangements have been concluded for the introduction of the Castner electrolytic process in the United States, and that a plant of this kind, now being erected at Saltville, Va., will probably go into operation during the present year. Electrolytic processes as applied to the bleaching of textile fibres, the production of chloroform, potassium chlorate, ozone, etc., have fully demonstrated their commercial value, and have taken rank among established industries.

In *telegraphy*, the improved system of Mr. P. B. Delany has been so recently described and illustrated in this hall that a mere brief reference to it will suffice at this time. Mr. Delany's machine system of recording and transmitting messages appears to contain all the elements of remarkable simplicity and high efficiency, notably in respect of speed in transmission, needed to enable the telegraph not only to hold its own against the competition of the telephone and other means of rapid communication, but also to take possession advantageously of a considerable portion of the mail service.

Direct Conversion of Heat into Electricity.—In the direction of cheapening the cost of generating electricity, by the conversion of heat into electric current directly without the intervention of the steam engine, some progress appears to have been made in increasing the efficiency of the thermopile; but the anticipations of those who had hoped for improvement in the direction of obtaining electricity directly from the combustion of coal, have met with disappointment. The experiments of Borchers with a gas battery deriving its electro-motive force from the oxidation of carbonic oxide, and which apparently demonstrated the feasibility of attaining the object aimed at by indirect means, have been subjected to searching criticism, and his results—if not actually invalidated—have been rendered doubtful. The problem, though admitted on theoretical grounds to be possible of solution. remains yet as perplexing as ever.

The proposition confronting the electrician has been concisely stated by Mr. C. J. Reed, a member of this Institute, in the following terms: "The problem is the conversion of the energy of fuel (including fuel gases, such as carbonic oxide and hydrocarbons) into electrical energy by oxidation, without transforming the energy into heat, and without the destruction of chemical reagents or the formation of waste products that require regeneration." In discussing the subject in a recent paper, published in *Cassiers' Magazine*, Dr. Duncan summarises the question in the following terms: "As to the possibility of solving the problem, he would be a rash man who would deny that in the future some one, by accident or by reasoning based on a fuller knowledge of electro-chemistry, might disclose a successful process. * * * I am myself confident that it will be discovered. Many men, most of them poorly equipped for the work, have been engaged on the problem, and some progress has been made. As for the method of solution, it must be remembered that the problem is: Electricity must be produced and nothing but fuel and air must be consumed. This points to two methods: either a gas battery must be used, or some substance must be discovered which will, in some way, convey the oxygen of the air to the carbon, without being itself decomposed." * * * "Finally, my conclusions are: (1) That the problem will be solved; (2) that the solution will be a simple one; * * * (3) that it will destroy the boiler and engine industries, and will seriously affect parts of the electrical industry; but it will cause a development in applications of electricity, far-reaching and helpful in the end to humanity."

Engineering.—In the field of engineering, perhaps the most notable event was the formal dedication to traffic, with imposing public demonstrations, of the ship-canal connecting the North Sea with the Baltic. The length of this artificial waterway is 61$\frac{3}{10}$ miles; its cost was $39,000,000.

The completion of the Harlem Canal, uniting the East and North Rivers, is a circumstance of much more importance from the commercial and strategic standpoints than its magnitude or cost would indicate.

Worthy of special mention among engineering works. in progress, is the great drainage canal of the city of Chicago, to which several extended references have lately been made in the *Journal*, and which is rapidly approaching completion.

The Nicaragua Canal project, for which at one time the outlook appeared highly favorable, has fallen upon evil days. Difficulties of a financial nature compelled the abandonment of active work some time ago, and the report of a Commission of Engineers, appointed by the Congress to investigate the company's plans and estimates, is currently believed to be of an unfavorable character.

At length, the long-mooted project of tunnelling the Simplon Pass has assumed definite form, the contract for the work having been let during the past year for the sum of $13,750,000. When completed, this tunnel will outrank all others in magnitude. It will be 12¼ miles in length, and will comprise two tunnels, spaced 56 feet apart, one for each line of rails.

Among railroad enterprises, the only item of prime importance to be noted is the steady progress made upon the great Trans-Siberian Railway which the Russian Government has been steadily pushing towards completion for a number of years, and which in due time will doubtless play an important part in the development of that great empire's Asiatic possessions.

It is, however, in the department of *naval and military engineering* that the greatest advances have been made. The persistent rivalry between the leading military powers has led to the construction of floating fighting machines of marvellous powers of offence and defence. The advances relate equally to the size and speed of warships, to improvements in the defensive qualities of armor and in the offensive power of guns and projectiles. It seems a singular perversion of the order of things that so much of the best effort of modern science should be devoted to the improvement of engines of destruction; but after all, the outcome may, and not unlikely will, be the speedier coming of the era of universal peace and good-will among the nations through the very agency that is constantly striving to make war more frightfully destructive.

One of the most interesting mechanical developments of the past year was the sudden coming into prominence of the self-propelling vehicle. The subject appears to have been attracting considerable interest in Europe, notably in France, for several years. Attention was first directed to the matter by the announcement of a public competition between representatives of the several classes of such vehicles in a trial race between Paris and Bordeaux, a distance of 358 miles. The performance of a number of these motor wagons demonstrated that a creditable degree of efficiency had already been reached in their construction and management.

The sudden awakening of interest in this subject which this event created in this country was demonstrated when one of the Chicago daily journals announced a prize competition for self-propelling vehicles, to take place in the autumn of last year. In both the number of competitors and the high grade of the vehicles entered in this trial, the event was remarkably successful, although the almost impassable condition of the road between Chicago and Milwaukee rendered it impossible to learn much about their relative merits in actual road performance. The first honor in this competition, it is interesting to note, was awarded to an electrically propelled vehicle, the power for which was furnished from storage batteries. To what extent the development of the self-propelling vehicle will be carried in the immediate future is, of course, problematical. There are substantial reasons, however, for the opinion that its use will rapidly extend, and that it will presently find a recognised place among the mediums of transit in town and country. In this country, unfortunately for the speedy success of such a movement, it will find itself handicapped, except in the immediate neighborhood of the large cities, by the wretched condition of the public highways. On the other hand, should it arouse only a moderate portion of the enthusiasm which is accorded to the bicycle, it may prove of substantial benefit in advancing the cause of good roads throughout the country.

In the field of *pure chemistry*, the greatest interest attaches to the verification of the discovery of "argon," a new constituent of the atmosphere, which Lord Raleigh and Professor Ramsey announced towards the close of 1894. The doubts that were at first expressed, respecting the genuineness of this notable discovery, have since been completely dissipated by the brilliant experimental work of those investigators who have isolated the new element and determined its constants. The fact that a hitherto unsuspected element —"argon"—forms a constituent of the atmosphere to the extent of 1 per cent. is now placed beyond question.

Professor Ramsey has added to the laurels gained in this classic research by the discovery of another new element found in the rare mineral clèveite. This element he succeeded in identifying, by its spectrum, with the hypothetical solar element, to which Mr. Lockyer, many years ago, gave the name of "helium."

CONDITION OF CARBON IN THE ELECTRIC ARC.

In a recent Cantor lecture before the London Society of Arts, Prof. Silvanus P. Thompson affirmed that the carbon in the crater of the electric arc was actually in the liquid state, and that the well-known phenomenon of the hissing of the arc is caused by the violent and noisy boiling of the liquid carbon. He adduces the following facts in support of this interesting view:

"Captain Abney had found the white surface of the luminous crater to be always of an equal degree of whiteness, which obviously means that it is always of an equal degree of temperature. * * * The only thing that could account for there being a fixed temperature for the crater surface was the fact that carbon is at the surface in a state of volatilisation; that the carbon is evaporating off from the positive carbon into the arc or flame. At that surface you necessarily must have the temperature at which carbon evaporates, just as you cannot have the surface of ice under ordinary conditions either hotter or colder than the temperature which is taken as zero of the Centigrade scale. * * * My present view of the physical state of the arc crater is that the solid carbon below is covered with a layer or film of liquid carbon just boiling or evaporating off.

"When hissing takes place, a new state of things is set up. If you watch a short, hissing arc, you will see a column of light concentrating itself on a narrow spot, and the spot keeps moving about, and is very unstable in position, as well as in the amount of light it gives out. The contracted spot from which light seems to start pits deeper into the carbon. * * * Mrs. Ayrton * * * made the observation that the crater surface, after the arc has been hissing, is found to be literally honeycombed. When the arc is hissing, you can see little bits erupted out, and the hissing seems to be comparable to the hissing which takes place in water just when it is beginning to boil. If you have some water being heated in such a way that there is not more than a certain quantity of heat given off from the surface, you have the water evaporating quietly, but you cannot get more than a certain quantity of heat given off per square inch of top surface of the water in that quiet way. If you force more tnan a certain quantity of heat to pass off per top square inch of the water, you find the water begins to break up internally, and you have bubbles formed below the surface ; the surface breaks up, the bubbles are thrown out, and you have a noisy phenomenon. I think you will find there is exactly the same kind of difference between the silent arc and the hissing arc as between quiet evaporation and a noisy boiling. When the arc is hissing, there is a sort of decrepitation, as though solid particles were being torn asunder to make way for something coming out."

EFFECT OF THE DROUGHT ON RIVER TRAFFIC.

The prolonged drought which prevailed from midsummer into early autumn, over the eastern section of the country, caused a serious interruption of the traffic upon many of the rivers. Its effect upon the coal trade is set forth in the following brief statement, which appears in a recent impression of the *Bulletin* of the American Iron and Steel Association :

"Among other damage done by the long and severe drought of the fall of 1895, was a total interruption in the shipment of coal from the Monongahela region down the Ohio River. A few days ago there were loaded in barges in the Pittsburgh harbor, and awaiting shipment on the first rise of the river of 12 to 15 feet of water, over 1,300,000 tons of coal, railroad iron, barbed wire, nails, and other commodities, equivalent to 43,333 carloads of 30 tons each, or 1,445 trains of 30 cars each. It has been calculated that if the trains were placed one after another in a solid train the locomotive would enter Cincinnati as the caboose was leaving Pittsburgh. The coal trade of the Kanawha region in West Virginia was also injured by the long drought. It is said that there were 7,317,000 bushels of coal in 509 boats and barges lying in the Kanawha River pools, waiting for a rise."

TEST OF SELF-PROPELLING VEHICLES.

The competitive trial of self-propelling vehicles, arranged by the Chicago *Times-Herald*, took place on Thursday, November 28th. The course of the trial race was from Chicago to Milwaukee, a distance of 54 miles. Only six machines actually took part in the trial. A much larger participation had been expected, but unreadiness and the wretched condition of the roads—which for miles "were unbroken snowbanks and slush"—were responsible for the non-appearance of a number of those announced as competitors.

The competing machines were the Duryea, of Springfield, Mass.; the Morris-Salom "Electrobat," of Philadelphia; the Mueller Motocycle, of Decatur, Ill.; the Macy, New York; De la Vergne, New York; Sturgis Electric Motocycle, Chicago.

Two of the machines only, both of them belonging to the class of petroleum motors, covered the entire distance. The first to reach the goal was the gasoline motocycle of Chas. E. Duryea, of Springfield, Mass., which covered the distance in 10 hours and 23 minutes. This is considered a highly creditable performance, in view of the condition of the roads.

The Mueller vehicle made the journey in 11 hours, 58 minutes. The other machines were taken over part of the course and withdrawn. The winning machine, notwithstanding the severity of the trial to which it was subjected, appeared to be none the worse for its work—a fact which speaks well for its design and construction, since the storm of the previous day is said to have had completely paralysed traffic in that district.

The outcome of these trials is unanimously conceded to have demonstrated the real value of the automobile vehicle, and the belief appears to be very generally entertained that the immediate future will witness the very general introduction of this form of vehicle. The advantages that would be derived from the general use of such vehicles, when considered only from the sanitary standpoint, would be very great; and, from the economical point of view, the problem would seem already to have been solved. W.

TECHNICAL NOTES.

A Scotch engineer, Mr. Smillie, has invented *a new steam pipe*, capable of withstanding extremely high temperatures. He winds a close coil of steel wire about a copper tube and solders the whole firmly by immersing the steel-wound pipe in a fusible alloy, which has a melting point above the temperature of the steam which it is to convey.

A new method of *soldering lead to lead* consists in using an amalgam of the metal. The two surfaces to be united are first cleaned by scraping; then there is interposed between them a thin layer of lead amalgam. The soldering iron is then passed over the line of junction. The heat liberates the mercury of the amalgam, and the finely divided lead, set free from the mercury, fuses and solders the two sheets.

The Mannesmann Tube Company (Germany) has built for its works a huge *wire fly-wheel.* It is described as being formed of a cast iron hub or boss, to which are attached two steel-plate discs or cheeks, about 20 feet in diameter. The peripheral space between the discs is filled in with some 70 tons of No. 5 steel wire, completely wound around the hub, the tensile resistance thus obtained being found to be far superior to that of any casting. This huge fly-wheel is driven at a speed of about 240 revolutions per minute, giving a peripheral velocity of 2·8 miles per minute, or, approximately, 250 feet per second.

BOOK NOTICES.

The Encyclopædia of Founding, and Dictionary of Foundry Terms Used in the Practice of Moulding, etc. By Simpson Bolland. First edition, first thousand. New York: John Wiley & Sons, 1894.

This work presents a brief encyclopædic description of the materials, tools, machinery and methods employed in the art of casting in all the useful metals. It includes, also, many useful formulæ in connection with the manipulation of metals in soldering, brazing, turning, galvanising, plating, refining, smelting, etc.

It will be found very useful to all who may have to do with these arts, whether as artisan or engineer. The present work may be regarded as supplementing the earlier works of the same author on foundry practice, which have met with a favorable reception. W.

Practical Instructions in Quantitative Assaying with the Blowpipe; containing, also, readily applied qualitative blowpipe tests. For the prospector, miner and assayer, and for use in colleges. By E. L. Fletcher, U. S. A. New York: John Wiley & Sons, 1894. (Price, $1.25.)

The author has endeavored in this volume to meet the demand for a condensed, practical and cheap hand-book on blowpipe assaying, adapted to the wants of the prospector, miner, and, incidentally, for students of mineralogy. It covers qualitative and quantitative methods suitable for the determination of minerals, ores and metals. Wet methods have been excluded, except such as are indispensable in parting in the gold assay and in the standard flame reactions. The author particularly commends the use of the Fletcher blowpipe furnace.

The book is well adapted for its intended purpose. W.

Justus von Liebig: His life and work. 1803–1873. By W. A. Shenstone, F.I.C., etc. New York: Macmillan & Co. 1885. Price, $1.25.

The Herschels and Modern Astronomy. By Agnes M. Clerke. New York: Macmillan & Co. 1895. Price, $1.25.

The two works above named are recent contributions to the "Century Science Series," edited by Sir Henry E. Roscoe, a series of biographical sketches of scientific worthies, written in a popular style, excellently adapted to familiarise the non-scientific reader with the works of the master minds who have contributed so largely to our intellectual advancement and material welfare. W.

The Horseless Age. A monthly journal devoted to the interests of the motor vehicle industry. Vol. 1, No. 1. November, 1895. New York: E. P. Ingersoll, 157–159 Wall Street. Price, $2 per year; single copies, 25 cents.

Journalistic enterprise is again strongly in evidence in the launching of a new journal devoted specially to the interests of an industry, as yet in its infancy, but which gives promise of lusty growth. From the widespread attention which the subject of motor vehicles is attracting, abroad and at home, there is little room for doubt that we will witness, in the next decade, great improvements in their construction, with a corresponding extension of their use for business and pleasure. The developments of the self-propelling vehicle may, indeed, rival that of the omnipresent bicycle in the past decade, whose popularity it seems not unlikely to share.

The enterprising publisher of *The Horseless Age* is evidently determined to take time by the forelock and to keep pace with, rather than to follow, the course of this unique industrial departure. If he has read the signs of the times aright, there should be a great future for his journal.

The initial copy before us makes a large quarto of some fifty pages, most of which are devoted to illustrations and descriptions of various forms of motor vehicles. It is well printed and makes a handsome appearance.

W.

Manual of Physico-Chemical Measurements. By Wilhelm Ostwald, Professor of Chemistry in the University of Leipzig. Translated, with the author's sanction, by James Walker, D.Sc., Ph.D., etc. London and New York: Macmillan & Co. 1894. Price, $2.25.

The present work is an admirable addition to the limited number of aids available to the chemist and physicist in performing physico-chemical measurements. The domain of physical chemistry, of late years, has grown so rapidly, and the methods and appliances have multiplied so greatly, that a work of this kind, which describes the newest methods of measurement, will prove very serviceable alike to the chemist, the physicist and the engineer.

W.

A Hand-Book for Surveyors. By Mansfield Merriman, Professor of Civil Engineering in Lehigh University, and John P. Brooks, Instructor in Civil Engineering in Lehigh University. First thousand. New York: John Wiley & Sons. 1895.

The present volume, which appears as a pocket-book containing 128 pages of text and 114 pages of tables, is a valuable addition to the extremely useful series of works which have already made Professor Merriman's name familiar to the engineering public.

It is designed for the use of classes in technical schools, and also as a field-book for surveyors, and the effort of the authors to discuss clearly and concisely, in accordance with the best-known methods, each of the topics involved, namely, land and town surveying, levelling and simple triangulation and topography, has resulted most successfully.

A separate chapter is devoted to each of these topics. The first, covering the fundamental principles, embraces what is deemed needful of the elements of geometry and trigonometry, and of mensuration as applied to the problems arising in surveying.

The second chapter contains a brief description of a few of the instruments in most common use, and takes up in detail, as an example, the survey of a farm. The surveys of United States public lands are also here described and illustrated.

Chapter II, on levelling and triangulation, embraces a discussion of the level and its adjustments and uses, and of the adjustment and comparison of transits and of tapes.

The book is provided with a set of trigonometrical and other tables, including a table of azimuths of Polaris at elongation on January 1st, from 1895 to 1910, and Professor Winslow's tables for the reduction of stadia readings. T.

Problems in the Use and Adjustment of Engineering Instruments. Forms for Field-Notes. General instructions for extended students' surveys. By Walter Loring Webb, C.E., Assistant Professor of Civil Engineering in the University of Pennsylvania. First edition. First thousand. New York: John Wiley & Sons. 1895.

The author here presents a series of problems to be worked out by the student in the field. His aim is, not to replace any general text-book on surveying, but "to supplement the general instructions of such text-books by such general directions that the student may work *alone*, aided only by such occasional help as may be given by one instructor looking after several parties."

The problems embrace linear measurements, chain surveying, compass, level, transit, plane table, sextant and barometric practice, the use of the planimeter and pantograph, and railroad surveying.

No attempt is here made to describe the instruments used, as the student is supposed to be already familiar with their construction and operation.

T.

Stand-Pipe Accidents and Failures in the United States. A chronological record of accidents, etc. By Wm. D. Pence, C.E., Assistant Professor of Civil Engineering, University of Illinois. With 37 illustrations, numerous tables and an index. New York: Engineering News Publishing Company. 1895. Price, $1.00.

The growing frequency of accidents to waterworks' stand-pipes has forced upon the attention of engineers the conviction that there must be something wrong either in the theoretical assumptions involved in their design and construction, or in the manner in which they are used, and the aim of the author in compiling a chronological record of accidents to, and failures of, stand-pipes in the United States has been to subject the facts and data gathered to careful analysis, with the view of finding a rational explanation of each case, and thus laying a foundation for the proper criticism of accepted theories and practice. The author's work has been carefully and intelligently done, and he has laid the engineering fraternity under obligations. W.

Franklin Institute.

[*Proceedings of the annual meeting, held Wednesday, January 15, 1896.*]

HALL OF THE FRANKLIN INSTITUTE,
PHILADELPHIA, January 15, 1896.

MR. CHARLES BULLOCK, Vice-President, in the chair.

Present, 61 members and 12 visitors.

The Secretary presented the annual reports of the Board of Managers, the Committee on Library, the Committee on Science and the Arts, the Chemical and Electrical Sections, and the Trustees of the Edward Cresson Medal Fund, which were accepted.

Mr. Lewis Nixon, late naval constructor, U. S. N., read a paper on "The Marsden Corn-Pith Cellulose," a new substance claimed to possess remarkable water-excluding properties. Mr. Nixon exhibited specimens of the product, and gave an illustration of the avidity with which it absorbed water. Some discussion followed the reading of the paper. The subject was referred for investigation and report to the Committee on Science and the Arts.

The Secretary presented his annual report, embracing a *résumé* of industrial progress. The tellers of the annual election made their report, whereupon the following members were declared elected to the offices set opposite their names, viz.:

For *President*	(to serve one year), . . .	JOSEPH M. WILSON.
" *Vice-President*	(" three years), . . .	CHAS. BULLOCK.
" *Secretary*	(to serve one year), . . .	WM. H. WAHL.
" *Treasurer*	(" " "), . . .	SAMUEL SARTAIN.
" *Auditor*	(" three years), . . .	SAMUEL H. NEEDLES.

For *Managers* (to serve three years).

WM. L. BOSWELL,
THOS. P. CONARD,
JAS. M. DODGE,
HENRY GAWTHROP,
ISAAC NORRIS,
THEO. D. RAND,
STACY REEVES,
COLEMAN SELLERS,

For members of the *Committee on Science and the Arts* (to serve three years).

ARTHUR BEARDSLEY,
HUGO BILGRAM,
FRANK P. BROWN,
JOHN H. COOPER,
N. H. EDGERTON,
G. M. ELDRIDGE,
F. L. GARRISON,
W. N. JENNINGS,
ARTHUR KITSON,
EDWARD F. MOODY,
C. J. REED,
E. ALEX. SCOTT,
COLEMAN SELLERS,
H. W. SPANGLER,
WM. H. WAHL.

On Mr. Fullerton's motion, duly seconded, it was

Resolved, That the question of the expediency of permitting members to vote at the annual election by letter-ballot be referred to the Board of Managers for consideration, and report to the Institute.

Adjourned.

WM. H. WAHL, *Secretary*.

JOURNAL

OF THE

FRANKLIN INSTITUTE

OF THE STATE OF PENNSYLVANIA,

FOR THE PROMOTION OF THE MECHANIC ARTS.

VOL. CXLI. MARCH, 1896. NO. 3

THE Franklin Institute is not responsible for the statements and opinions advanced by contributors to the *Journal.*

THE FRANKLIN INSTITUTE.

Annual Meeting, January 15, 1896.

MR. CHARLES BULLOCK, Vice-President, in the Chair.

THE MARSDEN CORN-PITH CELLULOSE.*

BY MR. LEWIS NIXON,
Late Naval Constructor, U. S. N.

The use of cellulose is so closely related to the subject of the buoyancy and stability of vessels at sea that it will doubtless prove interesting to explain, in a simple manner, some of the phenomena connected with the behavior of vessels under various conditions. Let us imagine a vessel which will ordinarily float upright in still water to be inclined by the action of some force. If, when the inclining force is removed, she tends to return to the upright position, she is said to be stable. If she removes further away from the upright, she is said to be unstable.

---

* [Marsden's Corn-Pith Cellulose is an entirely new American product. It is manufactured from the pith of the cornstalk or Indian maize into a granular form, and packed under pressure into the cofferdams of vessels; it acts as a perfect obturator, or water excluder, and is absolutely non-combustible.]

A block resting on a table may be tilted over to a certain angle and still fall back to its original position, while, if it goes beyond this angle, it will fall over on its side. So we may incline a vessel and, within a certain angle, she will, when the inclining force ceases to act, return to the upright; but if pushed over beyond this angle, she will capsize. The angle to which she can be pushed and still retain stability is called the range of stability.

For present purposes we may define the metacenter of a vessel as a point of intersection of the line of action of the buoyancy when the vessel is upright, with the line of action of the buoyancy when the vessel is inclined through a small angle.

The statical stability of a vessel may be defined as the effort which she makes, when held steadily in an inclined position, to return to the upright position. In a stable vessel the metacenter must be above the center of gravity.

A vessel that has great metacentric height is said to be "stiff;" one that has small metacentric height, and that is easily inclined, is said to be "cranky." The metacentric height, then, may be taken as a measure of a vessel's stability for ordinary angles of roll. The range of stability—that is, the angle of inclination at which stability disappears—is as important as the metacentric height.

A vessel may have great metacentric height and a small range of stability; yet one having small metacentric height might return to the upright if turned upside-down.

The metacentric height of vessels varies greatly. Our monitors have metacentric heights of from 10 to 14 feet; the battleships from 3 to 4 feet; protected cruisers, 2 to 3 feet; tugs and small gunboats, from 1 to 2 feet. Generally speaking, it may be said that the greater the height of the vessel out of the water, the greater the range of stability, though deep draught is just as important, and we have had to sacrifice somewhat in range of stability in order to get our vessels on light draughts.

When a vessel goes to sea, the action of the waves makes her roll. A vessel, like a pendulum, has, within limits, an approximately fixed time of oscillation; that is, she will roll through angles of 10° in about the same time that she will roll through angles of 5°. This being the case, we can imagine the periods between the successive impulses of the waves to be so timed that they will act just as a small child does in swinging a heavy man, by giving little pushes at the right time at each swing. In such a case we shall have very violent rolling, so great, in fact, as to roll the vessel over in case the range of stability is small. The friction of the water, however, reduces the angle of roll, generally, before it becomes so great as to become dangerous. Besides, the period is lengthened for great rolls, enough to sensibly decrease the danger of rolling over.

A great metacentric height brings the vessel up violently and quickly, making a short period; while the low metacentric height is associated with long period.

The combination which leads to heavy rolling is the synchronising of the half period of the waves with the period of rolling of the vessel. The largest wave observed in the North Atlantic was 2,750 feet long, and had a period of twenty-three seconds. However, ordinarily large storm waves are from 200 to 300 feet long, and have periods of from six to nine seconds. A vessel having a period of from three to four seconds, therefore, might often meet waves that would lead to violent rolling, so that she might have to cut across them transversely, or in some way destroy the synchronism. Very few men-of-war, however, have such short periods.

Gunboats are sometimes given comparatively great metacentric heights, but they are given bilge keels, or long projecting fins, to keep down the violent rolling. The reason that such gunboats are given such great metacentric heights is not, then, to make them better sea boats, for they usually have high sides and good ranges of stability, but because, if the best height were given them, they could not afford to lose any of it in battle.

This shows us why vessels, that would be easy in their movements at sea with a moderate metacentric height, giving them periods so long that most of the waves, instead of timing with the roll, would go by too fast to exert cumulative effects, are given great metacentric heights, leading to quick rolls, and making them poor gun platforms. This is, perhaps, right, in the main; but, naturally, the best way to proceed would be to determine on a proper metacentric height in designing a vessel, and then provide means for retaining it.

A hole in the side naturally lets in water, reducing the water-line area, upon which depends the metacentric height. The old wooden vessels were attacked by shell that made holes along the water-line, but the amount of water that entered was small, owing to the few hits, the swelling of the wood, and the fact that holes in wooden vessels could be comparatively easily plugged. A steel vessel under fire from modern ordnance is likely to receive a great many shots along the water-line, every one admitting water and causing a loss of metacentric height and range of stability. The first and most natural way of guarding against such water-line damage was to put a belt of armor all around the vessel, extending a few feet above and below the water-line. However, guns improved so rapidly that a thick enough belt could not be carried the whole length, so it was carried far enough to protect the machinery and give stability, even if the rest of the water-line plating should be destroyed, a thick under-water deck being carried from the ends of this thick belt to the extremities of the vessel.

Then again, in the protected cruiser, protection is given to the vitals of the vessel by a thick, curved, turtleback-shaped deck just above the water at the center of the vessel, curving down to below the water, where it meets the sides. Above this deck, to preserve the stability, numerous compartments are formed by water-tight metal bulkheads, so that only a small space may be flooded by one shot. However, there is a limit to subdivision, and few protected cruisers, with only the thick deck, could stand up long under a well-aimed fire from rapid-fire guns.

The use of some light substance along the slope of the protective deck to preserve the stability by displacing water that might enter, in conjunction with the protective deck, to keep the shells from going into the machinery spaces and the magazines, was the next important step. So cofferdams were worked along this slope next to the water, in which were placed empty cans, cork, etc. The French improved upon this by originating the use of cellulose in these cofferdams, which, when fired into, swells up under the influence of water and prevents further inflow. The simplicity and efficiency of this method of protecting the stability of ships commended it to our Navy Department, and, after exhaustive trials, it was adopted for use along the slopes of the protective decks of our protected cruisers and battleships. Thus, in the *Columbia*, the *New York* and the *Olympia*, there are protective decks of ample strength to keep out the shells of any vessels they are likely to engage, while their stability is protected by belts of cellulose several feet thick along the edges of these decks. The English armored cruiser *Blake* has no such protection for her stability, and would not have the same chances as the above vessels of our Navy in a sustained engagement.

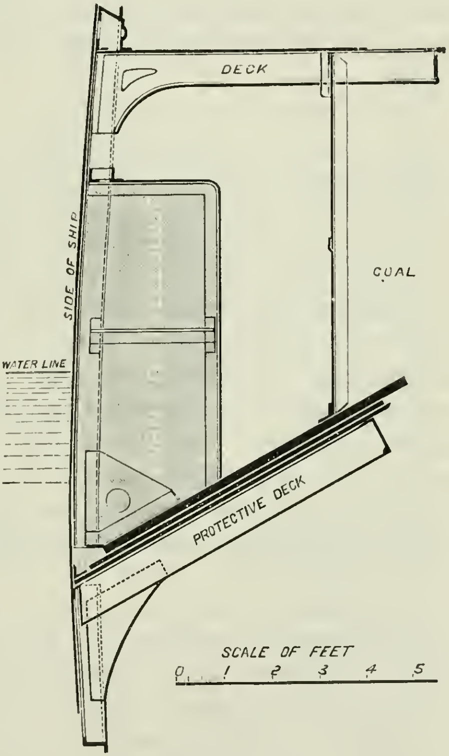


Fig. 1.

For keeping out water, a cellulose belt of 3 feet may be said to be about as efficient as a 6-inch belt of steel, so that we can protect our stability, when we have a good protective deck back of it to protect the vitals, with 100 tons of cellulose, where we should require 1,000 tons of armor.

The *Inflexible*, of the English Navy, was given 8½ feet of metacentric height, leading, even with her great moment of inertia, to the small period of 5½ seconds. This was on account of the fear that the unarmored ends beyond the armor belt might be blown away. Such damage is improbable, and, beside the range of a central citadel vessel, even with a fairly good metacentric height, would be so small that, with the ends blown away, the vessel would probably capsize.

So we may sum up, that what appears to be the present policy of our Navy Department, is not to give vessels abnormally great metacentric heights, as they want them to be at their best when they begin fighting, and not wait until they are dangerously punished before they become good gun platforms. The best way seems to be to fix a reasonable metacentric height, and then take means to keep it. The department's use of armor, armor decks and cellulose seems to meet this problem well. In vessels of high speed, where weight is needed for machinery and an armor belt cannot be carried, cellulose is used to preserve the stability, and an armor deck to protect the vitals. In battleships, thick armor is used amidships, which will always keep the vessel with some metacentric height, and a protective deck and cellulose belt are used beyond the limits of this armor.

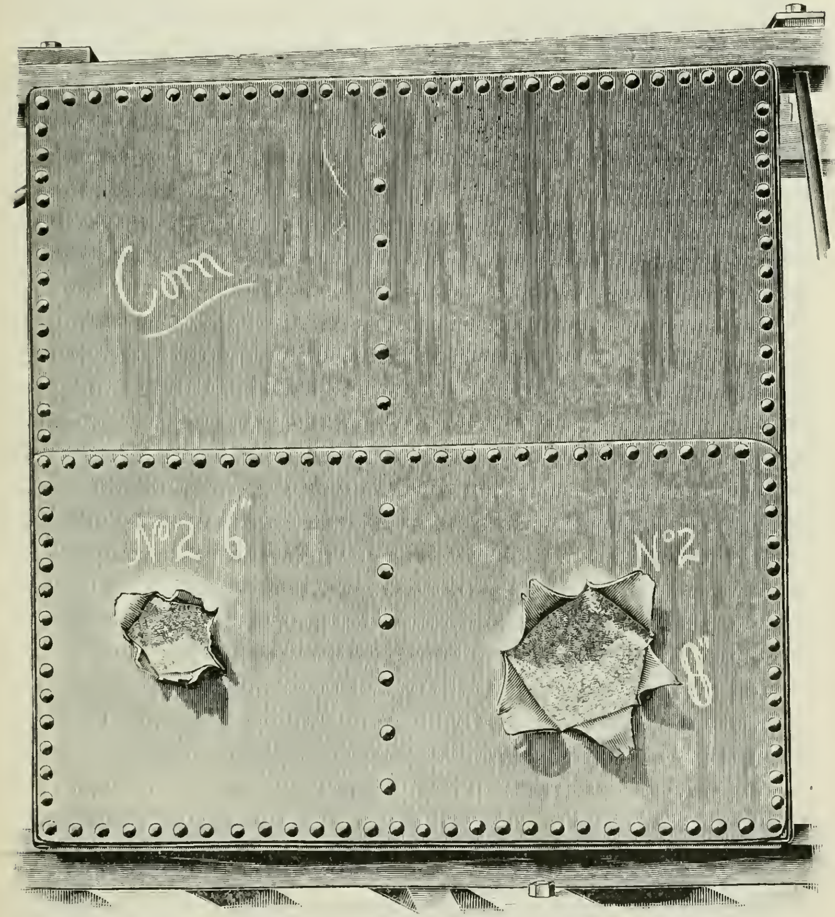
The cellulose first used by the Navy Department was manufactured in Philadelphia by the Franco-American Cellulose Company. It was made from the husks of the cocoanut, the cellulose proper looking like bits of ground cork, being separated from the fiber by specially built machines, and after certain processes, intended to prevent it from rotting and to render it incombustible, it was packed in the cofferdams, mixed with a certain amount of fiber to hold it together. The tests to which this cellulose was subjected were such as to produce an article superior to that used in France.

During the past year, the attention of the Navy Department was called to a new American product, manufactured from the pith of cornstalks or Indian maize, which substance, it was claimed, possessed qualities superior to those of the cocoa cellulose. This substance is made under the patents of Mr. Mark W. Marsden, of Philadelphia. By this process, it is necessary to secure the largest cornstalks, well matured and harvested at the proper time, which must be dried by either natural or artificial means, and, when in proper condition, passed through a cutting-machine, which cuts the stalks into suitable lengths, so as to be easily fed in an attrition mill especially designed for that purpose. As the stalks are cut, the leaves that have not been previously stripped from the stalks are blown aside. The stalk containing the pith passes through the mill, which cracks or breaks the shell and disintegrates the pith and fiber, which enter a chamber so regulated by air currents as to separate the pith and fiber from the outer shell, which go in opposite directions. The pith and fiber, having some dust in them, are passed on through an air current with a suitable device attached to discharge the dust into a separate compartment, the pith and fiber being by this time sufficiently separated so as to give the proper percentage of fiber with the pith. The pith and fiber being perfectly clean, and in proper proportions, a chemical compound is combined in such form and manner as to render them fireproof, and the substance is then ready to pack into a box, or to be pressed into blocks ready for shipment.

In order to make a test of the comparative value of these two products, the Navy Department had made two cofferdams of steel plates, stiffened by angles, 6 feet high, 6 feet wide and 3 feet thick. In one was placed 832½ pounds of cocoa cellulose and fiber, mixed to the usual proportions corresponding to a density of 7·7 pounds to the cubic foot. The other cofferdam was packed with corn cellulose containing 702 pounds, corresponding to a density of 6·5 pounds per cubic foot. These cofferdams were sent to the Indian Head proving ground, and were fired at on June 10, 1895. The first shot was fired at the cocoa cofferdam. A 6-inch shot, having a velocity of 1,000 feet per second, was fired into the cocoa cellulose with a gun, at a distance of 314 feet.

The hole made at the point of entry was the diameter of the shot, and that at the point of exit at the rear of the cofferdam was an irregular, jagged hole, 7½ inches by 8½ inches. The center of the hole was 5 feet below the top of the cofferdam. The passage of the shot caused a quantity of cellulose to be projected to the front through the hole made, and about a quart to be thrown out to the rear. Water was now applied to the front of the cofferdam, the level being 5 feet above the hole. In ten minutes, the first drop of water appeared through the cofferdam through the hole. The flow increased gradually, and, in a few minutes, had become comparatively steady, running about 12 gallons in one-half hour. The flow of one-half gallon a minute then became approximately constant. In the meantime, the cofferdam containing the corn cellulose was fired at under similar conditions. Water was turned on as before, and left for one and one-half hours, during which time no water whatever appeared at the hole in the rear of the cofferdam; nor, at the end of the time, had the corn cellulose at the mouth of the hole in the rear become damp. The cofferdam containing cocoa cellulose was now fired at with a 250-pound 8-inch shell, at the same distance and with the same velocity as that of the 6-inch shell. The hole in the front was the size of the shell. In the rear, a rough hole was made about 12 x 9 inches. About a pint of cellulose was thrown out from the front hole, and about one-half gallon from the hole in the rear. The water was then turned on with a head of about 5 feet, as before. In twenty-five seconds, a few drops appeared at the hole in the rear, and about 12 gallons had passed through in thirty minutes. In about half an hour, the flow had settled down to a practical steady rate, or about one-half gallon per minute. Under similar conditions, an 8-inch projectile was now fired at the corn cofferdam, the conditions of firing being the same in both cases. The water was turned on, and, after waiting forty-five minutes, no water appeared at the hole in the rear of the cofferdam, nor was the corn at the rear damp. No water had appeared at the 6-inch hole which had previously been made, nor was it damp at the completion of the experiment.

With a view of determining the relative resistances of the materials to washing-out effect of waves on the exterior of a vessel, a stream of water was turned on from a steam fire pump. The nozzle was held at 12 feet from the 6-inch holes in the front of the cofferdams, and directed full in these holes successively. At the end of 30 seconds, the material had been washed out in an elongated cone to a depth of about 18 inches from the surface in the case of the cocoa cellulose, and to a depth of 14 inches in the corn cellulose. It was



Inboard View of Shot-Holes Corn-Pith Cofferdam.

found by these experiments that there was no danger whatever of the cellulose material being washed out by the action of the sea, and thus failing to produce the obturating effects with either of the materials.

Tests were also made to show the relative non-combustibility of the materials. A portion of the material was placed loose in an iron envelope, a 3 pound shell containing $\frac{1}{10}$ pound of powder was exploded in its midst. A 1-pound bag of powder was exploded in a similar manner, in which case the cocoa cellulose ignited; the corn cellulose did not, but was greatly charred. Cocoa and corn cellulose were then packed separately in bags of a cubic foot capacity each, and two gallons of fresh water were poured into each box. The boxes were then placed in the basement of the Navy Department and examined from time to time. About a month later, it was found that the cocoa cellulose, which had been in contact with the iron, had turned black, and that the iron showed corrosion, except where painted, and there the paint under the action of the cellulose had softened. The corn cellulose showed that the painted portions were intact, and the paint was much firmer, and that in contact with the iron was only slightly black in some parts, and the iron very slightly corroded: hardly more would it have been the case had it simply been in contact with the moisture, showing that the corn cellulose had practically no effect.

After these exhaustive tests, which showed in a striking manner the superiority of the corn cellulose, the Navy Department's specifications for the battleships *Kentucky* and *Kearsarge*, the contract for which had just been awarded to the Newport News Ship Building Company, contained a clause requiring the cofferdams of these battleships to be packed with this substance.

Not only does the American cellulose show much greater absorptive and obturative powers than the cocoa cellulose, but it does not require to be packed to the same density. The cocoa cellulose is packed to 7½ pounds per cubic foot, and the corn cellulose to 6½ pounds. It is about $100 per ton cheaper than the cocoa cellulose, and this, with the lower density, makes it cost about two-thirds the amount per cubic foot packed; the fact that it is much easier to pack still further reduces its cost.

With the perfect obturation which can be obtained with the corn cellulose, naval designers can settle upon the metacentric heights and other features of their designs with confidence that they can be retained in an engagement. Our cruisers of the *Baltimore* type, if they are provided with a cellulose belt, would be warranted in engaging many of the second-class ironclads of other powers; without it they are liable to be sunk by a well-directed machine gun fire. This product of American farms affords a cheap and ready means of vastly increasing the efficiency of our cruisers, and the unarmored sides of all our vessels should have these belts without delay. This discovery and application of cellulose is of as vital importance to our Navy as the development of harveyised armor and smokeless powder.

This follows from the fact that without adding very much to the cost of our vessels, we can greatly increase the efficiency of them all by making their sides automatically resist the inflow of water, and, as our cruisers carry heavier batteries than similar vessels of other nations, they would, when so protected, be able to give battle to ships far heavier than themselves.

COMMERCE AND DEEPWATERWAYS.*

By Prof. Lewis M. Haupt, Consulting Engineer.

[*Concluded from p. 97.*]

THE MISSISSIPPI RIVER.

On February 17, 1892, the steamer *Hoxie* took a "tow," consisting of six freight barges and one coal barge, containing 8,566 tons, down the Mississippi. This load, if placed in 30-ton cars would have required 285, or, allowing 40 feet to the car, the train would have covered, without engines, 2⅛ miles of track. The average freight rates from St. Louis via New Orleans by water to Liverpool are 14 cents per bushel, as compared with 21 cents overland, via

---

* A lecture delivered before the Franklin Institute, December 13, 1895.

New York. The saving of this 7 cents per bushel, if applied to the grain shipments from New Orleans, for 1892, would represent nearly $500,000 saved on this one staple.

Although St. Louis is 1,355 miles from the Gulf by river, and only 946 by rail from New York, yet it will be seen that the water route can compete with the rail rate and still have a large margin. With an open deep-water port on the West Gulf Coast, but 720 miles distant, it can even then ship by rail to that port in competition with Eastern shipments; for if the ocean rate be taken at only $\frac{1}{10}$ that by rail, the 226 miles difference in favor of the Gulf would be equivalent to 2,260 miles at sea.

From the trans-Mississippi district it is estimated that at least an average of 500 miles may be saved in the overland haul by shipping from the Gulf instead of from the Atlantic ports, and a very simple calculation will give an idea of what this means to the United States.

If the railroad charge be taken at only 6 mills per ton mile, which is much below the average, a saving of 500 miles each way, or 1,000 miles in the round trip, means $6 per ton, or 18 cents per bushel on wheat, or its equivalent. For export alone (one way only) it is 9 cents, or at 22 bushels per acre, $2 would be added to the profits of every acre of wheat per annum. Thus the 1,000,000 square miles tributary to the West Gulf Coast, containing 640,000,000 acres, would be increased in value annually by $1,380,000,000 if they could be made to produce wheat or its equivalent—a value altogether beyond our ability to comprehend.

This will perhaps illustrate why the Government has made such persistent, vigorous efforts to secure deep water at Galveston, and why, now that the jetties are extended over the bar, recourse had been had to hydraulic dredging with the results previously mentioned.*

BRUGES,† BELGIUM.

Turning now to one of the oldest seaports of the continent, it will be found that the town of Bruges, in Belgium, is full of suggestion.

---

* For a history of this work, see *Franklin Institute Journal* of October, 1891. "The Galveston Harbor Problem."

† Page 135 of Jean's "Waterways and Water Transport," London, 1890.

"This Venice of the North lay formerly near the sea on a gulf of considerable depth, and was easily accessible to the largest ships. So capacious was her port that in the year 1213, Philip Augustus, at the head of 1,700 sail, closed in it with the allied English and Flemish fleets. So long as her communication with the sea remained open, Bruges maintained her commercial power; but the successive accumulations of clay in the Lwyn, and in the outer ports, caused the lamentable state of things which followed. In the latter part of the thirteenth century a canal was cut of such dimensions as to give access to vessels of from 400 to 500 tons, the largest then afloat. This so stimulated commerce that for fifty years, from 1420 to 1470, Bruges was the mart of the world, and her fortune reached its climax. But shortly before the discovery of America, the deposits in the Lwyn again interrupted commerce. Charles the Bold caused the polder of the Lwartegat to be opened, hoping to scour out the channel, but without success. Twelve years later the large draft vessels ceased to appear, and the canal which had maintained the marvellous prosperity of the old city was buried under the accumulated silt from the sea, and Bruges was condemned to a long decline. In 1622, the opening of a canal to Ostend was determined upon, and twenty years later one was dug from Bruges to Nieuport and thence to Dunkerque. In 1646, this latter port was surrendered to France and the Flemings were obliged to turn their attention to Ostend. The dimensions of the canal were greatly increased, and in 1717 the *Compagnie des Indes* was organised at Ostend, to increase the commercial movements. It was very successful at first, and would have restored to Bruges her former circulation and life, had not the Treaty of Paris, of 1727, inspired by the jealousy of Holland and England, suspended for seven years the grant of the company, and later, forbidden all commercial intercourse between the Austrian Netherlands and the Indies. Four years later the treaty of Vienna, of 1731, expressly stipulated 'that all commerce and navigation from the Austrian Netherlands to the East Indies, as also that all commerce and navigation from the East Indies to the Austrian Netherlands, shall cease forever.'"

In 1783, Joseph II, wishing to end the subjection of his provinces, undertook to build a canal to the sea, exclusively on Flemish ground, but failed in the attempt. It was only after the Netherlands had been joined to France that Napoleon ordered a canal to be dug from Bruges to Damme, but it was not completed before the fall of the empire. In 1829, King William resumed the scheme of Napoleon, and decided to push the canal to Breskens; but just before beginning, the revolution of 1830 again put an end to the hopes of Bruges and the people were in despair, when, in 1877, M. Ade Mære Limander proposed a ship canal to the sea at Ostend, 7½ miles, with moles and harbor works. The dimensions were: width at bottom, 65 feet; at top water surface, 204 feet; depth, 23 feet; slopes, ⅓. It was supplied with water from the sea. This canal has cost over $3,000,000, and has abundantly proven the wisdom of its projectors.

During the past four centuries, therefore, four distinct attempts have been made to restore communication between Bruges and the sea, three of which were unsuccessful, but not so much in consequence of the physical difficulties to be overcome as through political complications and national jealousies—factors which are still potent in restricting the construction and improvement of the waterways of the world.

A contract is now being executed to build a new seaport at " Heyst on the North Sea, at the mouth of the canal that will make Bruges once more a seaport large enough to hold fifteen of the largest trans-Atlantic steamers. The breakwater will stretch more than two miles out to sea. The port will cost $5,400,000, and $2,400,000 will be spent on the canal."

The experience of Antwerp is well known, but it may be well to add it to this record as an evidence of the benefits resulting from low taxes on vessels. Up to 1863 the Dutch Government taxed all vessels using the Scheldt to such an extent as to make it burdensome. A treaty was concluded that year by which, in consideration of certain specific payments made by the various countries whose ships used the river, that the dues should be renounced. Since then the trade of Antwerp has advanced by leaps and bounds. Between 1862 and 1887, the imports increased by 335 per cent., and the exports by more than 500 per cent. The general transit trade also increased 400 per cent., and the tonnage of vessels entering the ports advanced by about 600 per cent.

EXPERIENCE WITH THE SINGLE JETTY SYSTEM.

Bilbao, Spain.—Another remarkable instance resulting from the removal of an ocean bar is to be seen in the case of Bilbao, on the north coast of Spain, in the Bay of Biscay. Here a single curved breakwater was built by M. Churruca, to regulate the discharge of the river, and it was expected to secure a low-water depth of 20 or 22 feet. This work was completed about 1888, and the results were very satisfactory; the commerce increased immediately from 1,400,000 to 4,600,000 tons annually.

Greytown.—Another illustration of the efficacy of single jetties for removing bars is to be found in the case of the entrance to the harbor at Greytown, at the mouth of the Nicaragua Canal. Here a single but straight jetty converted a dry sand bar into a 15-foot channel, while at the mouth of the Columbia the single jetty has secured a depth of 30 feet over the once dangerous bar obstructing its entrance. The second jetty originally designed to be built has been found to be unnecessary.

One Jetty vs. Two.—The policy of maritime engineers the world over has been to construct jetties in pairs so as to concentrate, if possible, the ebb scour of the tidal waters over the outer bars; but experience has shown this to be at best a slow, expensive and unsatisfactory procedure, and of late years there has been considerable discussion as to the relative merits of single *vs.* twin jetties for ocean bar removal. Advocates of the submerged, convergent jetties in pairs, as designed for such cases as Charleston, Galveston, etc., have abandoned their theories, after practical tests, as untenable, and have substituted the high and compact stone jetties in pairs, aided by hydraulic dredging on the bar, requiring continual expense for maintenance.

Thus far, the single jetty, when placed originally on the side of the channel from whence comes the littoral drift, as required by the physical conditions of the entrance, has invariably been more or less successful.

Aransas Pass, Texas.—The latest application of this principle is now being made at Aransas Pass, Texas, the strategic commercial port of our Mediterranean Sea. Here a contract was let, last July, for the construction of a single reaction breakwater, to be built on the plans proposed by the writer, upon private capital, advanced by Messrs. Alex. Brown & Sons, of Baltimore, and, by the time the foundation mat was laid and covered with rock to a depth of only 2 feet and length of 1,250 feet, there was an increase in depth, on the channel side on the outer slope of the bar, of 7 feet, also a deepening of 6 feet beyond the outer end of the work, and a general breaking up on the crest of the bar, without any progression seaward. In reporting these facts after a few months' work. Mr. Brewster Cameron, the general manager, to whose energy this enterprise is chiefly due, wrote, on November 2d: "The results thus far have exceeded our expectations and surpassed your predictions, and have more than vindicated the wisdom of yourself and associates in reversing the order of harbor works and beginning the improvement on the outer slope of the bar."

A letter from Baltimore, of date November 22d, states that: "We fail to find any place with less than 13 feet of water on the bar," although the first portion of the breakwater was not completed to high water, and had not been extended as far landward as the crest of the bar. The prevailing depth, as reported by the U. S. Coast and Geodetic Survey of 1891, was 7¾ to 8 feet, so that this would indicate an increase of at least 4 feet, in a few months, entirely across the bar, even before the superstructure of the breakwater had reached its crest, a result which, it need hardly be added, is entirely unprecedented in the history of bar removal, by either natural or mechanical agencies. The measure of this result will be better understood by comparison with the harbor works at Dublin, concerning which it was reported:*

---

* *Vide Franklin Institute Journal*, April, 1888, "Jetties for Improving Estuaries."

There are few, if any, cases of bar entrance to any harbor being increased in depth like that of Dublin, viz.: about 7 feet in thirty years, and great credit is due those who designed, as well as those who executed, works which have achieved so important a result. The improvement of Dublin harbor ranks second to none. There is no other example, so far as the author is aware, of the construction of an artificial estuary for scouring purposes which has proved so successful."

The great North Wall at Dublin, to which all the beneficial results are ascribed, was built between 1819 and 1825, a period of six years. For a distance of 5,600 feet it rises to a height of 6 feet above high water, and is 30 feet wide on top; thence it slopes to the bottom, which it reaches at a distance of 9,000 feet from shore.

The rate of scour is shown from the following statement:

Date.	*Depth at Low Water.* *ft. in.*	*Interval in Years.*	*Increase in Depth* *ft. in.*	*Rate of Inc. Per Annum.* *in.*	*Depth at High Water.* *ft. in.*	*Mean Rise of Tide.* *ft.*
1822 . .	6 3	—	—	—	19 3	13
1828 . .	9 6	6	3 3	6·5	22 6	13
1833 . .	10 6	5	1 0	2·4	23 6	13
1856 . .	13 0	23	2 6	1·81	26 0	13
1873 . .	16 0	17	3 0	2·1	29 0	13
Totals,		51	9 9	2·3		

from which it appears that the total increase of depth is but $9\frac{3}{4}$ feet, the average scour being only 2·3 inches per year for over fifty years' time, with a tidal oscillation of 13 feet. The total volume of water estimated to pass through the jetties at each tide is 24,000,000 tons, or 31,600,000 cubic yards.

This slow but constant improvement in depth is attributable to the fact that a gap was left in the North Wall some 600 feet in length, to admit the tide more freely, thus producing a preponderance of ebb over flood movements in its exit through the entrance, 1,000 feet wide at low water.

The money expended at Aransas Pass, Texas, by private parties in 1869, and subsequently by the Government, has served its purpose in indicating the probable solution of the perplexing question of how best to secure a deep water entrance on the west gulf coast. A few quotations from this experience will, therefore, be quite pertinent. The reports of the chief of engineers for 1887 say, in substance:*

"Works were begun in 1880, and suspended in 1885. The Pass was moving southward at the rate of 260 feet per year. The depth over the bar varied. It was 9 feet in 1852, 7½ feet in 1868, 9½ feet in 1871, 7 feet in 1875, and 7 feet in 1878;" average, 8 feet, which was also the depth in 1892, when an official survey was made. The object of the Government work was: (1) "to stop the southward movement of the Pass;" (2) to deepen the channel over the bar at the entrance to 12 feet, and (3) to stop the erosion of the bounding islands by wind.

Results.—"The work designed to deepen the channel over the bar, consisting of a single jetty, constructed upon the south side of the entrance, has had no important effect upon the bar, and is in a dilapidated condition. The channel depth over the bar is now 8½ feet, and the channel crosses the jetty. The works designed to stop the erosion of the surface of the islands by wind, consisting of sand fences and plantations of salt cedars, have disappeared, and left no traces behind." The officer in charge, who had been but recently assigned to this district, therefore recommended a change of plan, consisting of two jetties, 2,000 feet apart at their outer ends, extending in parallel lines to the 20-foot curve, and rising to 5 feet above mean low water. "They are expected to secure and maintain a channel depth of not less than 20 feet." "The original estimated cost of this work, as here revised, is $2,052,543.72, and the amount actually expended is $383,618.02."

From the above it appears that this latter sum was spent with a resulting depth of only 8½ feet, or practically no improvement, while the present effort has produced an unprecedented movement of material at a cost not exceeding $113,000 spent to date of survey. It is, of course, too early to predict the final results from this single breakwater, and these are only stated for what they may be worth, but they are so unusual as to merit attention.

---

* August 6, 1887, Report Chief of Engineers.

It is not our purpose at this time to enter into the principles and operation of this design of breakwater, but only to call attention to it, as opening up a new and apparently remarkably cheap and rapid method of removing ocean bars, and of improving our commercial waterways, by the application of the reaction induced by concave dikes and jetties properly oriented with reference to the axis of the ebb and flood currents and littoral drift.

It may happen that by this treatment of the ocean bars obstructing our alluvial shores, they may be so readily and cheaply removed as greatly to stimulate the industries dependent upon ocean commerce, and also increase the demands already existing for a more vigorous and systematic deepening of our internal channels by rivers and canals.

Ten years have passed since the Interstate Committee reported, yet comparatively little progress has been made in the emancipation of the waters, upon which they laid great stress.

After a searching investigation, that committee found as follows:

"There are several important internal improvements which must soon be undertaken by the general Government if the United States are to keep step with the leading nations of the world in the grand march of progress. * * * The great European powers appear to be engaged in an earnest and determined contest for commercial supremacy. In this contest we cannot afford to be sidetracked, but must engage in the race for cheaper transportation with all possible energy and vigor.

"The cheapest mode of transportation known is by water. The railroads have accomplished wonders, but no railroad can successfully compete with a free and unobstructed water route, so far as the cost of carriage is concerned. Therefore, to secure the blessings of cheap transportation, and to hold our place among the nations of the earth, we must develop our natural waterways to their fullest capacity, and give the benefits of lake, river and canal communication to the people of all the States, so far as practicable. * * *

"The chief defects of the present water routes of the country, as a whole, are that they are too long for successful competition with the railroads, and that they are too isolated for successful co-operation. The obvious and only possible remedy for these defects is to *shorten* them and *unite* them (by canals). * * * By thus shortening the existing lines of water communication and rendering them navigable for steam vessels of large carrying capacity, the cost of freight service could be reduced to the lowest possible minimum, not only between a few great centers of trade, but between interior points in almost every part of the country.

"A comprehensive system of internal improvements would develop to their utmost extent the inexhaustible resources of the United States; would give new life and healthy activity to trade; would put bread in the mouths of thousands of men now seeking employment without success; would avert the dangers to be apprehended from railroad combinations to control the commerce of the country, and would secure rates of transportation that would always enable the surplus products of the nation to find a profitable market.

"The manifest destiny of our country points unerringly to this *emancipation of the waters*, as its next great work, a destiny not of war, but of beneficence and peace, to which the heart of the nation turns as spontaneously and resistlessly as the waters of its great river flow to the Gulf."

To bring about this consummation so devoutly to be wished, it is fundamental that we should fully appreciate our present possibilities and the defects of the system which has proven so inadequate to provide speedy relief. By way of comparison as to our internal waterways, it may be stated that in the United States:

	Miles.
The length of our ordinary canals was reported in 1890 to be	2,099·1
The length of maritime or river canals	179·4
The length of canalised rivers	1,070·2
Giving a total of only	3,348·7

for an area of 3,019,140 square miles; while France, with her territory of only 204,092 square miles (or nearly 60,000 square miles less than Texas), has 7,703 miles of improved river and canal navigation. This is at the rate of one mile to 27 square miles of area, while in the United States it is 1 to 1,000, very nearly.

The movement on the French waterways, which in 1880 reached 1,247,095,000 ton-miles, was increased to 2,117,400,000 in 1891, while the price of freights dropped to $\frac{3}{10}$ cent, or even less for .long distances. This is largely due to the unification of the gauge, so as to admit boats of 300 tons capacity, one of which is, therefore, equivalent to about ten of our largest freight cars.

The French Government has expended many hundreds of millions on these public works, and it is stated by their political economists that the canals, even when free, pay 5 per cent. per annum in economising the national wealth.

The work is under the supervision of the Corps des Ponts et Chaussées, a permanent organization of civil engineers, organized for this express purpose.

On this point the late Col. Wm. E. Merrill, of the United States Corps of Engineers, who built the Davis Island Dam, reported :

" As a final conclusion from the study of French and American experience in inland navigation, it may be stated that modern practice is decidedly in favor of the development of all the natural waterways of a country to their full capacity, and of the creation of as many artificial waterways as the financial resources and physical conditions of the country will permit ; that such waterways should be absolutely free of toll ; that they should be under the control of a permanent body of engineers wholly disconnected with politics ; and, finally, that the expenditures necessary to secure these results are profitable to the commonwealth, even though the profits do not appear in direct returns to the treasury."

These conclusions are unquestionably sound and commendable, yet the existing system of temporary assignments of officers in charge is not calculated to produce the best results. Our own port of Philadelphia has, for example, in the past twenty years been in charge of no less than eight officers, an average of two and one-half years each, with the result that the bars controlling the entrance, having depths of 20 feet and covering a length of 5 or more miles, are still in a state of nature, and our commerce has been largely superseded by that of our sister ports, New York, Boston and Baltimore, while ocean rates are so high, in consequence of the withdrawal of our largest steamers, that it is said it pays better to send our foreign freight to New York or Boston than to ship from the home port. It is to be expected, however, that the recent awakening of our citizens to the importance of providing suitable terminal facilities along the Delaware frontage, the removal of the islands, which has been rapidly prosecuted under the resident Government official, and the liberal appropriations of our municipal authorities, will measurably stimulate our foreign commerce and increase to some extent the transshipments from rail to water at this point. But it is likewise important that greater facilities should be provided for the passage and handling of our coastwise commerce along the safe interior lines, which may be provided by the enlargement of our existing tributary canals and the permanent removal of the bars at the head of the bay, which control the entrance to the river.

These are works of great moment to the welfare of our commonwealth. They should commend themselves to the personal sympathy and support of every one of its citizens, who should use every legitimate effort for the *accomplishment* of this laudable purpose.

The lecture was closed with views of the river Tyne, the coal engorgement at Pittsburgh, the Delaware River and Bay, the harbors of Philadelphia and Antwerp, and views along the canals, with the hydraulic dredging plants in use on the Pacific Coast for improving channels and reclamation of lands.

ON A NEW KIND OF RAYS.*

BY W. C. RÖNTGEN.

(1) A discharge from a large induction coil is passed through a Hittorf's vacuum tube, or through a well-exhausted Crookes' or Lenard's tube. The tube is surrounded by a fairly close-fitting shield of black paper; it is then possible to see, in a completely darkened room, that paper covered on one side with barium platino-cyanide lights up with brilliant fluorescence when brought into the neighborhood of the tube, whether the painted side or the other be turned toward the tube. The fluorescence is still visible at 2 meters distance. It is easy to show that the origin of the fluorescence lies within the vacuum tube.

(2) It is seen, therefore, that some agent is capable of penetrating black cardboard, which is quite opaque to ultra-violet light, sunlight, or arc-light. It is, therefore, of interest to investigate how far other bodies can be penetrated by the same agent. It is readily shown that all bodies possess this same transparency, but in very varying degrees. For example, paper is very transparent; the fluorescent screen will light up when placed behind a book of 1,000 pages; printer's ink offers no marked resistance. Similarly, the fluorescence shows behind two packs of cards; a single card does not visibly diminish the brilliancy of the light. So, again, a single thickness of tinfoil hardly casts a shadow on the screen; several have to be superposed to produce a marked effect. Thick blocks of wood are still transparent. Boards of pine 2 or 3 centimeters thick absorb only very little. A piece of sheet aluminum, 15 millimeters thick, still allowed the X-rays (as I will call the rays, for the sake of brevity) to pass, but greatly reduced the fluorescence.

---

* Translated by Arthur Stanton from the *Sitzungsberichte der Würzburger Physik-medic. Gesellschaft*, 1895.—*London Nature.*

Glass plates of similar thickness behave similarly; lead glass is, however, much more opaque than glass free from lead. Ebonite several centimeters thick is transparent. If the hand be held before the fluorescent screen, the shadow shows the bones darkly, with only faint outlines of the surrounding tissues.

Water and several other fluids are very transparent. Hydrogen is not markedly more permeable than air. Plates of copper, silver, lead, gold and platinum also allow the rays to pass, but only when the metal is thin. Platinum ·2 millimeters thick allows some rays to pass; silver and copper are more transparent. Lead 1·5 millimeters thick is practically opaque. If a square rod of wood 20 millimeters in the side be painted on one face with white lead, it casts little shadow when it is so turned that the painted face is parallel to the X-rays, but a strong shadow if the rays have to pass through the painted side. The salts of the metals, either solid or in solution, behave generally as the metals themselves.

(3) The preceding experiments lead to the conclusion that the density of the bodies is the property whose variation mainly affects their permeability, at least no other property seems so marked in this connection. But that the density alone does not determine the transparency is shown by an experiment wherein plates of similar thickness of Iceland spar, glass, aluminum and quartz were employed as screens. Then the Iceland spar showed itself much less transparent than the other bodies, though of approximately the same density. I have not remarked any strong fluorescence of Iceland spar compared with glass (see below, No. 4.)

(4) Increasing thickness increases the hindrance offered to the rays by all bodies. A picture has been impressed on a photographic plate of a number of superposed layers of tinfoil, like steps, presenting thus a regularly increasing thickness. This is to be submitted to photometric processes when a suitable instrument is available.

(5) Pieces of platinum, lead, zinc and aluminum foil were so arranged as to produce the same weakening of the

effect. The annexed table shows the relative thickness and density of the equivalent sheets of metal.

	Thickness. Millimeters.	*Relative Thickness.*	*Density.*
Platinum . . .	·018	1	21·5
Lead	·050	3	11·3
Zinc	·100	6	7·1
Aluminum . .	3·500	200	2·6

From these values it is clear that in no case can we obtain the transparency of a body from the product of its density and thickness. The transparency increases much more rapidly than the product decreases.

(6) The fluorescence of barium platino-cyanide is not the only noticeable action of the X-rays. It is to be observed that other bodies exhibit fluorescence, *e.g.*, calcium sulphide, uranium glass, Iceland spar, rock salt, etc.

Of special interest in this connection is the fact that photographic dry plates are sensitive to the X-rays. It is thus possible to exhibit the phenomena so as to exclude the danger of error. I have thus confirmed many observations originally made by eye observation with the fluorescent screen. Here the power of the X-rays to pass through wood or cardboard becomes useful. The photographic plate can be exposed to the action without removal of the shutter of the dark slide or other protecting case, so that the experiment need not be conducted in darkness. Manifestly, unexposed plates must not be left in their box near the vacuum tube.

It seems now questionable whether the impression on the plate is a direct effect of the X-rays, or a secondary result induced by the fluorescence of the material of the plate. Films can receive the impression as well as ordinary dry plates.

I have not been able to show experimentally that the X-rays give rise to any calorific effects. These, however, may be assumed, for the phenomena of fluorescence show that the X-rays are capable of transformation. It is also certain that all the X-rays falling on a body do not leave it as such.

The retina of the eye is quite insensitive to these rays; the eye placed close to the apparatus sees nothing. It is clear from the experiments that this is not due to want of permeability on the part of the structures of the eye.

(7) After my experiments on the transparency of increasing thicknesses of different media, I proceeded to investigate whether the X-rays could be deflected by a prism. Investigations with water and carbon bisulphide in mica prisms of 30° showed no deviation either on the photographic or the fluorescent plate. For comparison, light rays were allowed to fall on the prism as the apparatus was set up for the experiment. They were deviated 10 millimeters and 20 millimeters, respectively, in the case of the two prisms.

With prisms of ebonite and aluminum, I have obtained images on the photographic plate, which point to a possible deviation. It is, however, uncertain, and at most would point to a refractive index 1·05. No deviation can be observed by means of the fluorescent screen. Investigations with the heavier metals have not as yet led to any result, because of their small transparency and the consequent enfeebling of the transmitted rays.

On account of the importance of the question, it is desirable to try in other ways whether the X-rays are susceptible of refraction. Finely powdered bodies allow, in thick layers, but little of the incident light to pass through, in consequence of refraction and reflection. In the case of the X-rays, however, such layers of powder are, for equal masses of substance, equally transparent with the coherent solid itself. Hence, we cannot conclude any regular reflection or refraction of the X-rays. The research was conducted by the aid of finely powdered rock salt, fine electrolytic silver powder and zinc dust, already many times employed in chemical work. In all these cases the result, whether by the fluorescent screen or the photographic method, indicated no difference in transparency between the powder and the coherent solid.

It is, hence, obvious that lenses cannot be looked upon as capable of concentrating the X-rays; in effect, both an ebonite and a glass lens of large size prove to be without action. The shadow photograph of a round rod is darker in the middle than at the edge; the image of a cylinder filled with a body more transparent than its walls exhibits the middle brighter than the edge.

(8) The preceding experiments, and others which I pass over, point to the rays being incapable of regular reflection. It is, however, well to detail an observation which at first sight seemed to lead to an opposite conclusion.

I exposed a plate, protected by a black paper sheath, to the X-rays, so that the glass side lay next to the vacuum tube. The sensitive film was partly covered with star-shaped pieces of platinum, lead, zinc and aluminum. On the developed negative, the star-shaped impression showed dark under platinum, lead, and, more markedly, under zinc; the aluminum gave no image. It seems, therefore, that these three metals can reflect the X-rays; as, however, another explanation is possible, I repeated the experiment with this only difference, that a film of thin aluminum foil was interposed between the sensitive film and the metal stars. Such an aluminum plate is opaque to ultra-violet rays, but transparent to X-rays. In the result the images appeared as before, this pointing still to the existence of reflection at metal surfaces.

If one considers this observation in connection with others, namely, on the transparency of powders, and on the state of the surface not being effective in altering the passage of the X-rays through a body, it leads to the probable conclusion that regular reflection does not exist, but that bodies behave to the X-rays as turbid media to light.

Since I have obtained no evidence of refraction at the surface of different media, it seems probable that the X-rays move with the same velocity in all bodies, and in a medium which penetrates everything, and in which the molecules of bodies are embedded. The molecules obstruct the X-rays, the more effectively as the density of the body concerned is greater.

(9) It seemed possible that the geometrical arrangement of the molecules might affect the action of a body upon the X-rays, so that, for example, Iceland spar might exhibit dif-

ferent phenomena according to the relation of the surface of the plate to the axis of the crystal. Experiments with quartz and Iceland spar on this point lead to a negative result.

(10) It is known that Lenard, in his investigations on cathode rays, has shown that they belong to the ether, and can pass through all bodies. Concerning the X-rays, the same may be said.

In his latest work, Lenard has investigated the absorption coefficients of various bodies for the cathode rays, including air at atmospheric pressure, which gives 4·10, 3·40, 3·10 for 1 centimeter, according to the degree of exhaustion of the gas in discharge tube. To judge from the nature of the discharge, I have worked at about the same pressure, but occasionally at greater or smaller pressures. I find, using a Weber's photometer, that the intensity of the fluorescent light varies nearly as the inverse square of the distance between screen and discharge tube. This result is obtained from three very consistent sets of observations at distances of 100 and 200 millimeters. Hence, air absorbs the X-rays much less than the cathode rays. This result is in complete agreement with the previously described result, that the fluorescence of the screen can be still observed at 2 meters from the vacuum tube. In general, other bodies behave like air; they are more transparent for the X-rays than for the cathode rays.

(11) A further distinction, and a noteworthy one, results from the action of a magnet. I have not succeeded in observing any deviation of the X-rays even in very strong magnetic fields.

The deviation of cathode rays by the magnet is one of their peculiar characteristics; it has been observed by Hertz and Lenard, that several kinds of cathode rays exist, which differ by their power of exciting phosphorescence, their susceptibility of absorption, and their deviation by the magnet; but a notable deviation has been observed in all cases which have yet been investigated, and I think that such deviation affords a characteristic not to be set aside lightly.

(12) As the result of many researches, it appears that the place of most brilliant phosphorescence of the walls of the discharge tube is the chief seat whence the X-rays originate and spread in all directions; that is, the X-rays proceed from the front where the cathode rays strike the glass. If one deviates the cathode rays within the tube by means of a magnet, it is seen that the X-rays proceed from a new point, *i. e.*, again from the end of the cathode rays.

Also, for this reason the X-rays, which are not deflected by a magnet, cannot be regarded as cathode rays, which have passed through the glass; for that passage cannot, according to Lenard, be the cause of the different deflection of the rays. Hence, I conclude that the X-rays are not identical with the cathode rays, but are produced from the cathode rays at the glass surface of the tube.

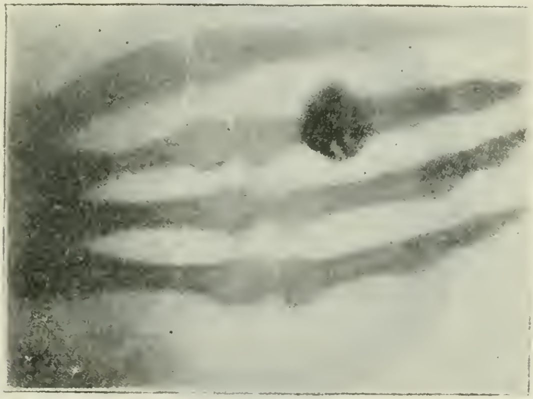


FIG. 1.

(13) The rays are generated not only in glass. I have obtained them in an apparatus closed by an aluminum plate 2 millimeters thick. I purpose later to investigate the behavior of other substances.

(14) The justification of the term "rays," applied to the phenomena, lies partly in the regular shadow pictures produced by the interposition of a more or less permeable body between the source and a photographic plate or fluorescent screen.

I have observed and photographed many such shadow pictures. Thus, I have an outline of part of a door covered with lead paint; the image was produced by placing the discharge tube on one side of the door and the sensitive plate on the other. I have also a shadow of the bones of the hand (*Fig. 1*), of a wire wound upon a bobbin, of a set of weights in a box, of a compass card and needle completely enclosed in a metal case (*Fig. 2*), of a piece of metal where the X-rays show the want of homogeneity, and of other things.

For the rectilinear propagation of the rays, I have a pinhole photograph of the discharge apparatus covered with black paper. It is faint, but unmistakable.

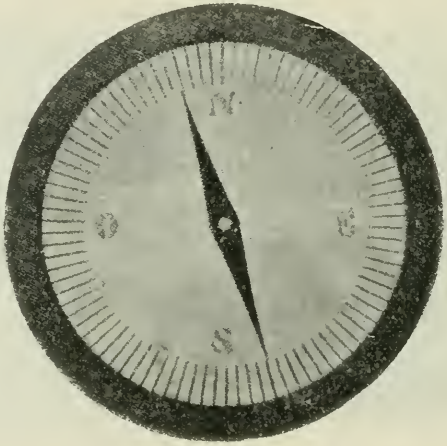


FIG. 2.

(15) I have sought for interference effects of the X-rays, but possibly, in consequence of their small intensity, without result.

(16) Researches to investigate whether electrostatic forces act on the X-rays are begun but not yet concluded.

(17) If one asks what, then, are these X-rays; since they are not cathode rays, one might suppose, from their power of exciting fluorescence and chemical action, that they are due to ultra-violet light. In opposition to this view a weighty set of considerations presents itself. If X-rays be, indeed,

ultra-violet light, then that light must possess the following properties:

(*a*) It is not refracted in passing from air into water, carbon bisulphide, aluminum, rock salt, glass or zinc.

(*b*) It is incapable of regular reflection at the surfaces of the above bodies.

(*c*) It cannot be polarised by any ordinary polarising media.

(*d*) The absorption by various bodies must depend chiefly on their density.

That is to say, these ultra-violet rays must behave quite differently from the visible, infra-red, and hitherto known ultra-violet rays.

These things appear so unlikely that I have sought for another hypothesis.

A kind of relationship between the new rays and light rays appears to exist; at least the formation of shadows, fluorescence, and the production of chemical action point in this direction. Now, it has been known for a long time that, besides the transverse vibrations which account for the phenomena of light, it is possible that longitudinal vibrations should exist in the ether, and, according to the view of some physicists, must exist. It is granted that their existence has not yet been made clear, and their properties are not experimentally demonstrated. Should not the new rays be ascribed to longitudinal waves in the ether?

I must confess that I have, in the course of this research, made myself more and more familiar with this thought, and venture to put the opinion forward, while I am quite conscious that the hypothesis advanced still requires a more solid foundation.

CHEMICAL SECTION.

Stated Meeting, December 17, 1895.

DR. WM. C. DAY, President, in the Chair.

MODERN THEORIES OF ELECTROLYSIS.

BY DR. JOSEPH W. RICHARDS, of Lehigh University.

All science is based on the observation of phenomena, which supplies us with facts. The orderly arrangement of these facts, their tabulation and classification, give us *descriptive science.* The natural questioning of the human mind as to the why and wherefore of these facts, and especially of the observed relations between groups of facts, gives us *theoretical science.*

Regarding the observed relations between phenomena, a probable guess as to the wherefore of these relations is an *hypothesis.* When the hypothesis agrees with almost all the known phenomena, explains them naturally and satisfactorily—and, especially, if it be substantiated by rendering predictions which are afterwards verified by observed new facts—it constitutes a *theory.* When the theory is so completely proven that no exceptions can be cited to its operation, it then rises to the dignity of a *natural law.*

The subject in hand to-night does not, therefore, directly deal with the facts of electrolysis, or the verified laws of electrolysis, but with the attempts to explain the observed facts and the proven laws by postulating relations which have not yet been fully proven. It will be necessary, however, to review, in a concise manner, those facts and laws, in order to reach a better understanding of the theory.

We may class all bodies, provisionally, as conductors and non-conductors of electricity, although the division is not an exact one. Non-conductors require a very high potential to pass an electric current through them. No trace of conduction appears until this very high potential is reached; then the material suddenly gives way, so to speak, as if the electric force had literally torn a path through it.

Conductors are substances which conduct electricity to some degree, at the lowest potentials.

We can distinguish two kinds of conductivity—metallic and electrolytic. A metallic conductor transmits electricity without exhibiting any chemical or physical change, except that it becomes heated by the passage of the current. The conductivity of metallic conductors decreases with rising temperature, and *vice versa*, and in such a ratio as to make the assumption plausible that, at the absolute zero (— 273° C.), their resistance becomes zero. Thus, the electric conductivity of aluminium at 0° C. is 50 (silver being 100), while at — 220° C. it conducts nine times better than at 0°; so that, compared with silver at 0° C., its conductivity would be in the ratio of 450 to 100. At — 273° C., the conductivity of metallic conductors is infinite; there is no resistance to the passage of the current.

Electrolytic conductors transmit electricity; but, in doing so, suffer a chemical change. They are necessarily compound bodies, and they are separated into two constituents, which appear, respectively, at the electrodes, *i. e.*, the points where the metallic conductors bringing the current come in contact with the electrolytic conductor, or electrolyte. A direct current causes these constituents (*ions*) to gather on the electrodes, and, if the current be suddenly interrupted and the wires connected with a galvanometer, a counter current traveling in the reverse direction from the original one will be observed, caused, no doubt, by recombination of the separated ions. We might compare this to an elastic recoil. Metallic conductors show no trace of such spring-back or recoil. The conductivity of electrolytes increases with rising temperature; in fact, most of them are to be regarded as practically non-conductors in the solid state at ordinary temperatures, and only become conductors when rendered liquid by a solvent or by fusion.

We have, therefore, three very striking points of difference between metallic and electrolytic conduction. The difference between an electrolytic conductor of high resistance and a weak dielectric (non-conductor) is, however, not so clear; but time will not permit a discussion of this point this evening.

Amongst the non-conductors we may catalogue:

Fluorine, chlorine, bromine, iodine, oxygen, sulphur, if pure, and their compounds with hydrogen when these are pure liquids.

Ammonia and its compounds conduct badly, or not at all. Metallic organic compounds, *e. g.*, zinc methyl, are non-conductors.

Hydrocyanic acid, carbon-bisulphide, benzol, ether, toluol, naphthaline and many organic liquids are insulators, at least for a tension of 140 volts.

Many substances are non-conductors in the solid state, and conductors when melted. Faraday, in his experimental researches, catalogues the following salts as of this class:

Oxides of potassium, lead, antimony, bismuth; chlorides of potassium, sodium, barium, strontium, calcium, magnesium, manganese, zinc, copper, lead, tin, antimony, silver.

Iodides of potassium, zinc, lead, tin, mercury; fluoride, cyanide, sulpho-cyanide and chlorate of potassium.

Nitrates of potassium, sodium, barium, strontium, lead, copper, antimony.

Sulphates of sodium, lead, mercury.

Phosphates of sodium, potassium, calcium, copper, lead.

Carbonates of potassium, sodium.

Borates of sodium, lead, tin.

Chromates of potassium, lead.

Sulphides of potassium, antimony.

Kohlrausch makes a wider generalisation, and states that the chlorides, bromides, iodides, fluorides, oxides and sulphides of lithium, sodium, potassium, rubidium, cæsium, beryllium, magnesium, calcium, strontium, barium, aluminium, cerium, thorium, and the rare earths, are all, when in the *molten state*, good electrolytic conductors. Their aqueous solutions are also good electrolytes; but as the metals decompose water, their hydrates are usually deposited by secondary action. The corresponding salts of copper, silver, gold, zinc, mercury and cadmium behave similarly, being good conductors when melted, while the metal *can* be obtained from the aqueous solution. On the other hand, Kohlrausch classes the following as non-conductors, when molten :

> Sulphur, phosphorus, sulphur iodide, stannic iodide and chloride, arsenious chloride and sulphide, boric acid, sugar, wax, shellac, stearin, spermaceti, camphor.

Faraday thought he could draw the conclusion from his experiments that a compound, to be capable of electrolysis, must contain an equal number of atoms of a different kind in its molecule, and that those which contain more atoms of one substance than of another in their molecule are non-conductors. This has proved to be a very imperfect generalisation, having since been disproved experimentally by exceptions in both directions, while modern chemistry has repudiated many of the formulæ on which he based his hypothesis.

Kohlrausch made a generalisation which modern research has so far not subverted, but rather confirmed : "No simple, unmixed substance is an electrolyte at ordinary temperatures, though many are when heated." The corollary of this is that "all bodies showing electrolytic conductivity at ordinary temperatures are mixtures of simple substances." Pure water was long thought to be an exception to this rule; but it has recently been shown by this investigator that the freer the water is from impurities the poorer is its conductivity, and he has prepared water whose conductivity at 18° C. is only 0·04, that of mercury being 10,000,000,000. The specific conductivity in reciprocal ohms in this case would be only 0·000000042, or the resistance of a column 1 centimeter square by 1 centimeter long, 23,809,523 ohms. It was not certain that this water was absolutely pure, so that Kohlrausch's generalisation, in the light of our present knowledge, still stands as practically true.

Faraday was the first to place on a firm foundation our knowledge of the quantitative relation between the strength of an electric current (its quantity) and its power to effect chemical decomposition. Starting with the idea that chemically equivalent quantities of the elements represent equivalent quantities of chemical combining energy, Faraday's greatest discovery was that "equal quantities of the electric current do an equal amount of chemical work; that is, set free from combination, chemically equivalent quantities of the elements." There is no need here to expatiate on this well-known and well-established law. The momentous inference from it was, that a certain definite quantity of electricity appears to associate itself with chemically equivalent weights of the elements, and that each valence, or bond of chemical combining power possessed by an element, appears to require a definite amount of electricity for its dissociation. This law has already done good service in chemistry in helping to fix the combining power of elements whose valence was in doubt.

However, the *quantity* of an electric current is only one factor in the expression for its energy. Quantity multiplied by intensity equals energy. Ampères multiplied by volts equals work. Faraday knew that there was an intensity factor associated with the decomposition of a compound, but he lacked the grand work of Thomsen in chemical energy, and of Joule in electrical mechanics, which would have enabled him to penetrate the mazes of this part of the subject.

Since Faraday's time, Thomsen, Berthelot and the numerous workers in thermo-chemistry, have measured accurately the heat set free in chemical combinations, and have thus given us thermal equivalents for the energy of chemical affinity. Joule, on the other hand, has given us the quantitative relation between thermal, mechanical and electrical energy. Thanks to this new science, based on the conversion and conservation of energy, we are now able to understand the exact relations between chemical and electrical energy. We know the chemical energy of a combination expressed in heat energy. We can convert this into electrical energy by Joule's constants. But as we already know, by Faraday's law, the *quantity* of the electric current taking part in the decomposition of the substance, we have the data from which to calculate the intensity, or potential, which it must have—since energy divided by quantity equals intensity.

For example:

1 ampère × 1 volt = 1 watt = 0·24 gram-calorie per second.
1 ampère sets free from water, 0·00001035 gram of hydrogen per second.
1 gram of hydrogen requires to liberate it from water, 34,500 gram-calories.
0·00001035 gram of hydrogen requires 34,500 × 0·00001035 = 0·357 gram-calorie.
Voltage required $\frac{0·357}{0·24} = 1·49$ volts.

In other words, if 1 ampère, at a potential of 1 volt, represents an energy of 0·24 calorie per second, while the amount of chemical work performed for 1 ampère in liberating hydrogen in the same time is 0·357 calorie, then it follows that the 1 ampère must be at a potential of 1·49 volts, in order that the energy of the current should be equal to the chemical work which it is doing (0·24 × 1·49 = 0·357).

The relations of electrical, mechanical, thermal and chemical energy may be thus recapitulated:

1 coulomb (C) = the unit of electrical quantity.
1 volt (V) = " " " " potential.
1 V × 1 C = 10,000,000 absolute units of work (centimeter-gram—second system.)
$1\ V \times 1\ C = \frac{10,000,000}{98,060,000}$ = 0·1020 kilogrammeter of work.
= 0·2385 gram-calorie.
1 C flowing *per second* = a current of 1 ampère (A).
1 A × 1 V = 1 watt = 0·2385 gram-calorie *per second.*
= 0·1020 kilogrammeter of work *per second.*
= $\frac{1}{735}$ of a French horse-power.
= $\frac{1}{746}$ of an English horse-power.

1 A (1 coulomb per second) liberates 0·00001035 gram of hydrogen per second.

Therefore, 1 gram of hydrogen carries with it

$$\frac{1·00000000}{·00001035} = 96,540 \text{ coulombs};$$

$$\text{but } 1\ C \times 1\ V = 0·2385 \text{ calorie};$$

therefore, for every volt required to liberate a chemically-equivalent weight, in grams, of an element, the expenditure of energy is

$$96{,}540 \times 0{\cdot}2385 = 23{,}040 \text{ calories;}$$

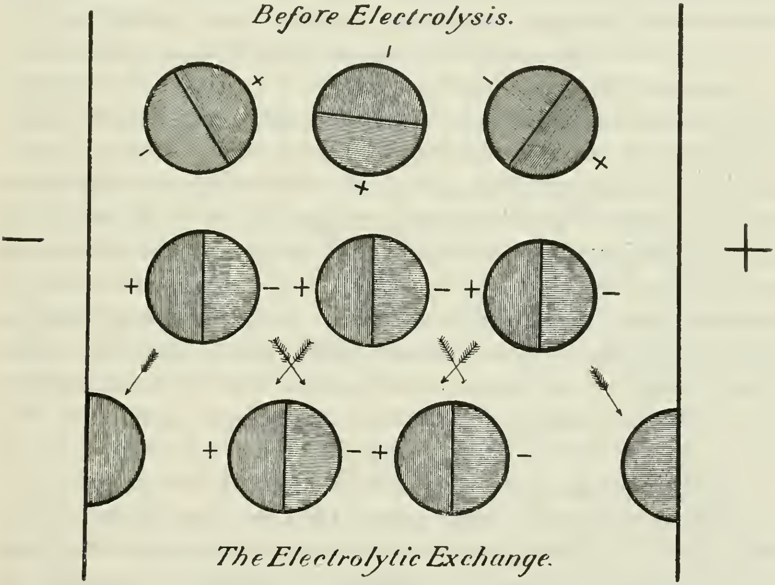
and if Q be the quantity of heat given out by the combination of an equivalent weight of an element, in grams, the voltage required to liberate it from that combination is

$$V = \frac{Q}{23{,}040}.$$

It thus becomes possible to calculate the voltage theoretically required to electrolyse any combination of which the heat of formation is known.

The converse of this law is that the electromotive force of a galvanic cell will be given by dividing the algebraic sum of the heat set free in the chemical reactions taking place in the cell (calculated per chemical equivalent of metal dissolved or deposited) by 23,040, which latter quantity we may conveniently designate as the chemical-thermal equivalent of 1 volt.

Taking up the different theories which have been advanced to account for the facts of electrolysis, and leaving out of consideration the score or more of rather wild guesses hazarded by various philosophers, we may say that the germ of our modern theories is contained in the writings of Grotthus, as far back as 1805. Starting with the observed fact that the constituents of an electrolyte appear only at the terminals, or electrodes, and that no trace of them in an uncombined state can, by any means, be detected in the mass of the electrolyte between, Grotthus advanced the idea that each constituent retained its positive or negative character while in combination; that when the terminals are charged by connection with a battery the attraction of the poles is felt throughout the liquid, so that the molecules, heretofore having their constituents pointing at haphazard in any direction, are polarised by the electric attraction, and arrange themselves in a chain with their positive constituents all pointing towards the negative pole, and *vice versa.* This is the idea often referred to as the "Grotthus chain." When the attraction of the poles for the constituent in immediate proximity to them is stronger than the force binding the two constituents together, then the molecule at each pole is disrupted, the constituents are set free at the poles, while an interchange of partners takes place simultaneously along the whole chain, the positive constituent of each molecule uniting with the negative constituent of the next one back of it, and *vice versa*. In the accompanying diagram (*Fig. 1*), the upper arrangement shows the molecules in fortuitous position before the application of the current; the middle row represents the molecules polarised in a chain by the influence of the charged terminals; the third row represents the arrangement after one exchange along the chain. Of course, the real number of molecules in the chain is probably millions to the inch; the diagram is intended merely to illustrate the mechanism of the change.


Before Electrolysis.

The Electrolytic Exchange.

FIG. 1.

This theory of Grotthus, promulgated in 1805, explained wonderfully well the facts of electrolysis as far as they were then known, and became untenable only when, in consequence of the acceptance of the dynamic theory of Clausius, in 1846, it became necessary to admit that the molecules could not thus be held at rest in a chain, but must be continually in a state of rapid motion. Grotthus' theory would also require that the concentration of the molecules in the solution should remain equal at all points between the electrodes, which is contrary to the facts discovered by Hittorf. The conception, however, on which this century-old theory is based, is still useful in leading up to the later conceptions, which may, in some measure, be styled only modifications of the older idea to explain more-recently-discovered facts.

Clausius' theory as to the dynamic constitution of gases, when extended to liquid and solid bodies, introduced modifications into the conceptions of the *modus operandi* of electrolysis. Clausius assumes that the molecules of a substance are in continual rapid motion, frequently colliding with one another, and probably often exchanging constituents with one another, so that a given atom may be, at successive intervals, united with different other atoms, and not always with the same one, as older conceptions fancied. This theory, applied to gases and worked out mathematically, explains so strikingly the fundamental gas laws that the truth of its conceptions is verified to a high degree.

Applying the idea to electrolytes, and bearing in mind Faraday's laws, we would conceive that the electric force influences the direction of the ions at such instants as they are changing from one molecule to another, at which instants they may be regarded as being potentially free from combination, and, therefore, susceptible to the directing force of the current. Only bodies thus capable of momentary dissociation into their ionic constituents will be capable of electrolysis. The result of this momentary pull on the ions, while they are changing partners, is to give them a directing tendency toward the electrodes. At the electrodes, the electric pull is strong enough to split the strongest molecule and attract to itself one ion, while the other finds new partners to combine with on its path toward the other electrode. Each ion, therefore, brings to, or neutral-ises at the electrode, a definite quantity of electricity, and the current is thus conveyed by a species of *convection* through the electrolyte.

To use a homely illustration, imagine a ball-room, filled with couples of ladies and gentlemen waltzing and frequently exchanging partners. Then let us suppose that at the one end of the room there was opened to view something which powerfully attracted the attention of the ladies—let us say an exhibition of laces—while at the other end something was shown equally attractive to the gentlemen—if you like, the base-ball score-board. Now, while dancing in couples, both being equally attracted toward the opposite ends of the room, the movements of the couples would be practically uninfluenced by the attractions, but, *while changing partners*, each would be certain to be influenced so as to move toward the end of the room attracting them. The result would be, the ladies all moving toward one end, the gentlemen toward the other; and when the couples nearest to the ends separated in order to find new partners, the one attracted by that end would find itself free to remain there. Call the company the electrolyte, the couples the molecules, the individuals the ions, and the attractions the electrodes, and you have, I think, an exact realisation of Clausius' theory.

With your kind permission, I will try to carry the illustration still further. Supposing the attraction of the exhibits at the ends of the ball-room to be so strong that those who once reach them have no desire to re-engage in the dancing, but are held permanently there—the result would be a gradual breaking up of the company, the floor being thinned out gradually until all were gathered at the ends of the room. This represents the case when the electric potential is greater than the force holding the ions together in the molecule, and then we have continuous electrical decomposition to a finish.

Let us now imagine the attractive forces weaker. They would still exercise a directing influence on the ladies and gentlemen; but if the attraction was not so strong as the desire of the persons to dance, we can readily imagine that those who were disengaged at the exhibits, after satisfying their curiosity, would turn their attention again toward the dancing, and it is certain that an accumulation of ladies, let us say, wishing partners, would constitute an attractive force on the gentlemen, which would soon become strong enough to neutralise the attraction at the other end of the room, and *vice versa.* Under these conditions the dancing might still go on, and yet a continually-changing company of temporarily-disengaged persons would always be seen viewing the attractions, which a person looking at, for the first time, might consider as representing so many permanently-disengaged couples. This condition represents the case when the electric potential is less than is theoretically necessary to separate the ions from each other and decompose the compound. With a low potential we have an accumulation of ions *to a minute extent*, on the electrodes, but the accumulation reaches a certain amount, and then stops. The higher the potential, the greater the accumulation, but it can never pass a certain limit. The strength of the desire of the persons gathered at the ends to re-engage in the dancing is measured by their real love of dancing minus the strength of the attraction which drew them there.

While the attracting force, therefore, remains less than the love of dancing, there will always be couples engaged in dancing, and the gatherings at the ends of the room cannot absorb all the dancers. While the acting electric potential remains less than the force with which the atoms tend toward each other in the molecule, there cannot be complete decomposition of the electrolyte, there can only be a gathering of ions on the electrodes, which cannot surpass a given ratio *to the number of momentarily free ions in the electrolyte.* When the acting potential just equals the theoretical voltage necessary for complete decomposition, this ratio becomes unity; that is, as many ions are set free at the electrodes in a given time as are set momentarily free, or as are potentially dissociated in the body of the electrolyte during the same time; and from then on, the ions accumulate without limit in quantitative proportion to the quantity of electric current passing, until the electrolyte is completely decomposed. This, however, would be an extremely slow operation. But, suppose the acting potential measurably larger, the ions are then forced apart through the body of the electrolyte, and form a steady procession toward each electrode. In other words, when the attraction of the electrodes is greater than that of the ions for each other, they incontinently take leave of each other and set up a procession toward each electrode, as we might imagine the ladies and gentlemen separating throughout the length of the ballroom and setting up processions toward each end, passing each other, with some friction it may be, and possibly the gentlemen making more rapid progress toward their end than the ladies toward theirs.

The last sentence gives the key to the valuable discoveries of Hittorf. It was well known before his time that, when electrolysing a solution, it gradually becomes impoverished around one electrode and concentrated around the other, if means are taken to prevent diffusion during the experiment. Hittorf, for instance, electrolysed a copper sulphate solution with an insoluble anode, using two porous partitions to separate the electrolyte into three compartments, one containing each electrode and one midway between (see *Fig. 2*). After passing the current for some time, it was found that the solution in *B* was much weaker than that in *C*, while the strength of the solution in *A* remained unchanged. On analysing the solutions and weighing the copper deposited, it was found that 64·4 per cent. of the copper had come from compartment *B*, and only 35·6 per cent. from compartment

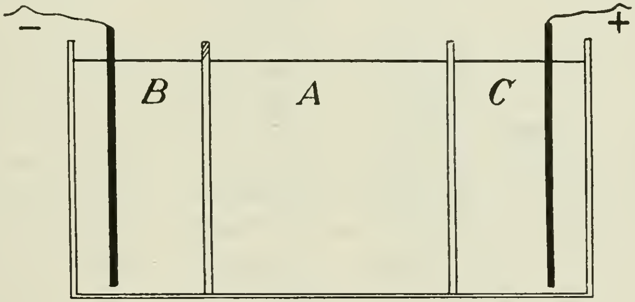


FIG. 2.

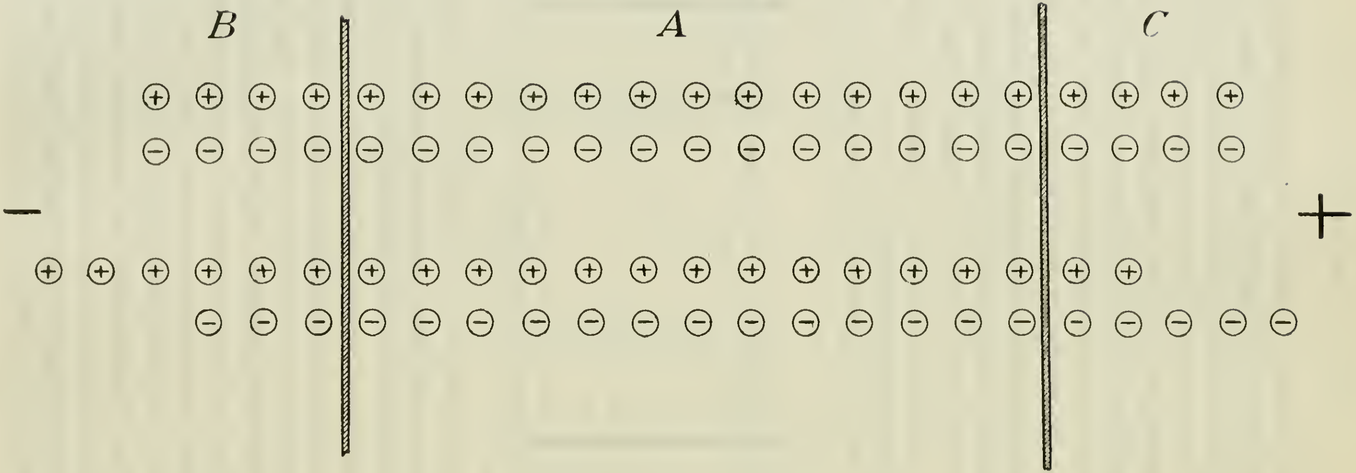


Fig. 3.

C. Using the same apparatus, Hittorf tested the salts of many metals with analogous results.

The question at once arises: "What is the reason for this?" Hittorf's explanation is as follows:

The changes of concentration are satisfactorily explained by supposing the ions to migrate through the electrolyte toward the electrodes at a different rate of speed. If they moved with equal velocity, each outside cell would lose an equal number of couples in a given time; if, however, one moved faster than the other, the outside cells would lose a different number of couples, which would change the concentration in the cells. If, for instance, in *Fig. 3*, the ions passing toward *B* move twice as fast as those moving toward *C*, then, while just the same number of + ions will be set free in cell *B* as of — ions set free in cell *C;* yet after a given time there will remain more undissociated couples on the *B* side of a central line, or of the central cell *A*, than on the *C* side, and the concentration of the liquids in the outside cells will be unlike. In fact, the relative velocities of the two ions will be found by determining the relative number of couples broken up or disappearing from the two end cells. If twice as many molecules, or twice as much salt, have disappeared from the *C* cell as from the *B* cell, it shows us that the ion moving toward *B* moves twice as fast as the ion moving toward *C*, as can easily be seen by a study of *Fig. 3*.

Hittorf thus determined migration values for the velocities of the ions in many electrolytes, and found that the quantity of the current passing had no influence on the relative velocities of the ions, but that the concentration of the solution under examination had considerable influence. Starting with a concentrated solution, the relative velocities of the two ions changed as the solution was diluted, *until a certain dilution was reached, after which there was no further change in the relative velocities.* This behavior was found to be characteristic of all electrolytes.

The application of Hittorf's discoveries to the study of aqueous solutions decided many vexed chemical problems. For instance, does tin tetrachloride exist in solution, or is it a mixture of stannous chloride and hydrochloric acid? On applying his methods to the study of stannic chloride solution, Hittorf found that the tin had no migration value at all—it stood still; and further, the chlorine traveled toward the anode with exactly the same velocity as did chlorine in a dilute solution of hydrochloric acid. The conclusion was certain, therefore, that there was hydrochloric acid in the solution, the hydrogen of which, evolved at the cathode, reduced tin from the *stannous chloride* present. In a similar manner, it was proven that the ions of some complex salts were quite different from what they had formerly been supposed, for instance:

Salt.	+ *Ion.*	— *Ion.*
K_4FeCy_6	K_4	$FeCy_6$
$KAgCy_2$	K	$AgCy_2$
Na_2PtCl_6	Na_2	$PtCl_6$
K_2HgCl_4	K_2	$HgCl_4$

Kohlrausch made the next great advance in our knowledge of the mechanism of electrolysis. He devised extremely accurate apparatus for measuring the conductivity of electrolytes. If we take the conception of Faraday and Clausius that electrolytic conduction is a species of electric convection from one electrode to the other, then the conductivity should depend simply on the number or concentration of the electricity-carrying ions between the electrodes. If the solution be diluted one-half, there will be only one-half as many ions between two fixed electrodes of given size, and therefore the electric conductivity should be exactly one-half; or the conductivity should be exactly proportional to the number of ions between the electrodes. Expressing it in another way, the conductivity should be inversely as the dilution of the solution.

Kohlrausch introduced a new expression. He calls λ the molecular conductivity, that is to say, the electric conductivity divided by the relative number of molecules between the electrodes. For instance, the molecular weight of potassium chloride is 74·5. A solution containing 74·5 grams of this salt to 1 liter is called a normal solution, whose concentration is 1, because it contains a molecular weight, in grams, in one unit of volume. Dilute this to 2 liters by adding pure water, and the solution would then be said to have a concentration of one-half, or a dilution of two. If the specific conductivity of the normal solution (compared to mercury = 100,000,000) is 918, then the specific molecular conductivity would be

$$\frac{918}{1} = 918.$$

The conductivity of the dilute solution being 474, the molecular conductivity for this dilution is $474 \div \frac{1}{2} = 948$, one-half being the concentration.

Kohlrausch examined solutions up to dilutions of 100,000, and determined, with great precision, that the molecular conductivity *increased* with increasing dilution, until it reached a certain limiting value, characteristic of each salt, after which it remained constant. The limiting values of the molecular conductivity were thus determined for solutions of numerous salts, and a discussion of these values soon revealed very interesting relations. It was easily observed that there was an approximately constant difference between the molecular conductivity of similar salts of similar bases. For instance, Ostwald found

$HCl - NaCl = 281{\cdot}8$

$HBr - NaBr = 282{\cdot}1$

$HI - NaI = 280{\cdot}6$

$KCl - NaCl = 22{\cdot}8$

$KBr - NaBr = 22{\cdot}5$

$KI - NaI = 23{\cdot}0$

If these differences are constants, it follows that the molecular conductivity of a salt is composed of two factors, one of which depends on one constituent and one on the other, and that the molecular conductivity is merely the sum of the conductivities of the ions.

It was not a difficult step to connect this conductive capacity of the ions with the differing velocities of the ions, or their "migration values," determined by Hittorf. (Kindly bear in mind we are considering here merely conductivity, and not decomposition.) The conductivity of the salt is the sum of the conductivities of its ions, but these are proportional to the velocities of the ions; therefore, the conductivity of the salt is proportional to the sum of the velocities of the ions, that is

$$\lambda = u + v$$

Now, if in a given time the anion moves a distance n, while the cation in the same time moves $1 - n$, the relative velocities u and v are as n to $1 - n$; therefore,

$$v = n \lambda$$

and

$$u = (1 - n) \lambda$$

n being Hittorf's migration number for the anion.

Using Hittorf's migration numbers for the ions, and combining them with his own determinations of the limiting molecular conductivities, Kohlrausch calculated the following ionic conductivities:

K	= 52	Cl	= 54
Na	= 32	I	= 55
Li	= 24	NO_3	= 48
Ag	= 42	ClO_3	= 42
H	= 272	$C_2H_3O_2$	= 26
½ Ba	= 30	OH	= 143
½ Mg	= 26		
½ Zn	= 24		

The sum of the ionic conductivities of K and ClO_3, for instance, gives the molecular conductivity of $KClO_3$.

It is worthy of remark, at this point, that the heats of formation of chemically-equivalent weights of salts are also strictly additive quantities, being the sum of factors characteristic of each ingredient, if the heats are taken for the formation of the salt dissolved in excess of water, *i. e.*, *in dilute solution.* This analogy between the molecular heat of formation in dilute solution and the specific molecular conductivity in dilute solution is certainly interesting, and possibly points the way toward many discoveries in the direction of deducing molecular properties from the constants of the atoms.

We will next take up the developments in electrolysis, due to the acuteness of Arrhenius (1882). He viewed the question of the increase of molecular conductivity with increasing dilution up to a certain limit, in a different light from his predecessors. He imagined this peculiar conduct to be due to the fact that, in general, not all the molecules between the electrodes take part in carrying the current, but only a part of them are "*active*" and another fraction "*inactive*." This distinction of active and inactive molecules is of the greatest importance in the evolution of Arrhenius' ideas. The increase in molecular conductivity with dilution would, therefore, be due to an increase in the proportion of active molecules, until when all became *active* the molecular conductivity reached its maximum, and, after that, further dilution would have no effect.

Now, the idea of *active and inactive mass* was a conception already introduced into chemistry by Guldberg and Waage, and Arrhenius put to the test at once the query whether the proportion of *active molecules* as determined by the molecular conductivity had any relation to the *active mass*, which measures the facility of a material to take part in chemical reactions. The result of the experiments, confirmed later by numerous experimenters, and in particular by Ostwald, was a complete identification of the two functions. For instance, Arrhenius measured the molecular conductivities of seven acids at similar dilutions, and the relative numbers obtained compared as follows with the relative avidities of these same acids, as determined in purely chemical ways by Thomsen:

RELATIVE AVIDITIES.

	From Chemical Tests.		*Calculated from Conductivity.*
Nitric acid	100	(standard)	100
Hydrochloric acid	98		92
Hydrobromic acid	89		86
Hydriodic acid	79		92
Sulphuric acid	49		47
Phosphoric acid	13		22
Acetic acid	3		8

These measurements of Thomsen were not as satisfactorily made as could be wished, and Ostwald devised other much more reliable and accurate chemical tests of the avidities of the acids, viz.: the speed with which the acid inverted cane-sugar, and the catalysis of methyl-acetate. Taking the activity of hydrochloric acid as 100, Ostwald examined thirty-four acids, whose relative avidities varied from 100 to 0·4, and compared this series with the molecular conductivities expressed on the same scale (HCl = 100). The result was a most striking proof of Arrhenius' ideas, the deviations between the chemical and electrical series being in every case within the experimental errors. It was, therefore, proved, at least for these thirty-four acids, that the facility of reaction, or relative avidity, varies directly as the molecular conductivity for electricity, *i. e.*, as the proportion of active molecules.

The question at once arose: "In what respect do the *active* differ from the *inactive* molecules?" Arrhenius supposed at first that the *inactive* were polymerised molecules, which on dilution became depolymerised, and, therefore, *active.* The further developments, however, soon caused him to drop this idea and to advance one of the most startling theories of modern chemistry.

The next step was made by studying carefully the law according to which the molecular conductivity increases to a maximum, for this must also be the law governing the change in chemical avidity. Kohlrausch had observed that with acids conducting well (strong acids) the relative increase in molecular conductivity, on dilution, was not so great as the relative increase in the molecular conductivity of weaker acids. In very weak acids the molecular conductivity increased nearly as the square root of the dilution. He also observed that if one acid conducted better or worse than another at any dilution, it did so at all dilutions; they never changed their relative positions on dilution. It thus appeared that the molecular conductivities of the acids must all be approaching the same limiting value, and that at infinite dilution the molecular conductivities, and therefore the relative avidities of the different acids, become all alike; in this case all the molecules have become *active.* At lower dilutions the activity of the acids are in direct proportion to the relative number of active molecules, *i. e.*, to their molecular conductivity.

Ostwald showed further, by his experiments on the thirty-four acids, that the limiting value of the conductivity of bibasic, tribasic and tetrabasic acids is sensibly only one-half, one-third and one-fourth that of an *equivalent* solution of a unibasic acid. To have the same degree of activity at great dilution, it is therefore necessary to compare, *not equivalent, but molecular* quantities of these acids. That is, at great dilution,

$$HCl = HI = HBr = H_2SO_4 = H_3PO_4 = H_4C_2O_2.$$

It therefore results that the active ions of these latter acids cannot be

$$H_2 - SO_4,\ H_3 - PO_4,\ H_4 - C_2O_2,$$

but must be

$$H - HSO\ ,\ H - H_2PO_4,\ H - H_3C_2O_2.$$

This rule is true of all polybasic acids, and deviations from the rule at lower dilutions are caused by differences in the degree of partition into *active* and *inactive* molecules.

Arrhenius' ideas were further developed under the influence of Van't Hoff's discoveries of the osmotic pressure of solutions.

Van't Hoff prepared diaphragms impervious to salts in solution, but permeable to water. On placing such a diaphragm over the mouth of an inverted funnel, as in *Fig. 4*, nearly filling this with pure water and placing it in a solution of cane-sugar, the water is seen to rise in the stem of the funnel to balance the pressure exerted by the sugar molecules against the diaphragm. By very careful experiments, with more complicated apparatus, it was found that the pressure thus exerted (osmotic pressure) was exactly the same pressure as would be exerted by the same quantity of sugar if it occupied the volume of the solution and *existed in the gaseous state* at the temperature of the experiment. In other words, if we imagine the water of the solution all removed, the sugar to be gasified in the same space, its resulting gaseous pressure is the same as the osmotic pressure, or the pressure with which it tends to diffuse through the impermeable membrane. Even further than this, it has been shown that the osmotic pressure increases $\frac{1}{273}$ for each degree of rise in temperature—exactly the gas coefficient. The equation for osmotic pressure is therefore the well-known gas formula

$$p\,v = R\,T.$$

To illustrate briefly: A molecule of sugar weighs 340 ($H = 1$). If dissolved in water to 1 liter of solution, its volume becomes 1 liter. But if gasified at 0°, its vapor would theoretically occupy 22·3 liters; therefore, if compressed into one liter, its pressure would be 22·3 atmospheres. If a solution contained only 10 grams of sugar to the liter, the osmotic pressure should be $\frac{1}{34}$ of 22·3 atmospheres, or 0·656 atmosphere at 0°. Pfeffer measured the osmotic pressure of this solution at 0° as 0·649 atmosphere. Many other solutions have been investigated with equally striking results.

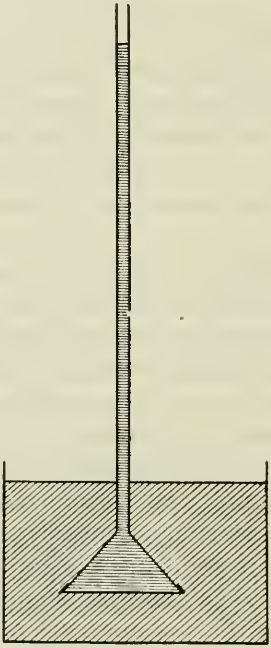


FIG. 4.

However, some solutions investigated by Van't Hoff showed a deviation from the above rule. They gave greater osmotic pressures than the formula required—up to double the pressure—so that for these cases the formula had to be written

$$p\,v = i\,R\,T$$

where i was a factor varying up toward a value of 2. It was also observed that in such solution the deviation from the gas law increased with the dilution, so that i approached 2 as the liquid approached infinite dilution.

Arrhenius was the first to notice that all the solutions showing this anomalous behavior were *electrolytes*, and to advance the idea that in such solutions the salts were already partly separated into their ions, which increase in the number of molecules would explain the increase in the osmotic pressure, and cause the irregularities in the boiling and freezing points of such solutions observed by various experimenters.

We have thus reached a statement of the modern theory of electrolytic dissociation into ions in solutions. In 1887, Arrhenius made a memorable communication on this subject to the Stockholm Academy, in which he connects his new ideas with his older discoveries in the following words:

> "The difference between *active* and *inactive* molecules consists in that the first are split into their *ions;* the latter not.
>
> "Only the free ions take part in the conducting of electricity and in chemical reactions; thence results the proportionality between the properties of electric conductivity and chemical activity.
>
> "The ions behave in the solution as independent molecules; thence result the deviations which electrolytes show from Van't Hoff's gas law for osmotic pressure."

The next step in the evolution of this theory, the proof of these propositions, was to be found in determining experimentally the parallelism of these deviations; in other words, to show that the variations in the coefficient i of Van't Hoff's formula are identical with the variations in molecular conductivity and chemical activity noted by Arrhenius.

If we let

i = the relation between the real number of molecules present and that called for by the formula of the undissociated compound (Van't Hoff's coefficient);

a = the fractional number of molecules dissociated (Arrhenius' proportion of *active* molecules);

n = the number of ions into which each molecule dissociates;

then

$1 - a$ = the fractional number of undissociated molecules, and, by definition,

$$i = \frac{n\,a + (1 - a)}{1} = 1 + (n - 1)\,a.$$

But if, as Arrhenius postulates, the molecular conductivity varies directly as a, and, at infinite dilution, a becomes equal to 1, then it follows that the value of a at any given dilution is simply the ratio of the molecular conductivity at that dilution (μ_v) to the molecular conductivity at infinite dilution (μ_∞), or

$$a = \frac{\mu_v}{\mu_\infty}$$

and, therefore,

$$i = 1 + (n - 1)\,\frac{\mu_v}{\mu_\infty}$$

This reasoning predicted and rendered necessary the above simple relation between the deviation of the osmotic pressure of a solution from the simple gas law, and its variations in electric conductivity; between which quantities no relation had ever before been suspected.

To test this formula, Arrhenius investigated ninety solutions, twelve of which were non-conductors, fifteen contained bases, twenty-three acids, forty salts. The truth of the relations affirmed, or, rather, predicted, was proven decisively, and, later, more exact determinations have confirmed it even more strikingly.

If this theory of electrolytic dissociation really be a law of nature, then the following conclusions must be true:

(I) Since the ions are independent of each other, it does not matter with what element they were formerly united before dissociation; and the properties of the salt solution, at the limiting dilution where a equals 1, must become the binary sum of the properties of the two ions; all its properties must be strictly additive.

We have already seen how Kohlrausch has proven that the molecular conductivity at the limiting value is an additive quantity, and I also wish to call attention again to my previous observation that the heat of formation of the salts, in dilute solution, is also a strictly additive quantity.

> (II) Only the *ions* show chemical activity. Therefore, as soon as an element exists in solution, *not as a simple ion*, but as part of a complex ion, it shows no longer the characteristic reaction of that element. For instance, the ions of KCl are K and Cl, and silver nitrate precipitates the chlorine; but in $KClO_4$, the ions are K and ClO_4; Cl is no longer an ion, and silver nitrate no longer shows its presence in the solution.

Time does not permit me to dwell longer on the development of this theory, on the struggles of Arrhenius, Van't Hoff, Ostwald, Planck, Nernst and others, to convince the doubting world of science of its truth.

Ostwald and Planck proved that the law regulating the increase in molecular conductivity on dilution is the identical law governing the *dissociation of a gas into two constituents*, which is derived from mechanical considerations and confirmed by experiment. Budde and Kohlrausch calculated the absolute velocities of the ions through the electrolyte, from which could be deduced the mechanical force necessary to give the ions this velocity. For instance, it requires a force of 330,000,000 kilos to force the atoms of hydrogen through an electrolyte at the rate of 0·003 centimeters per second. This is not the force which holds the ions together, but only the force required to overcome the friction of the ions in passing through the solution. Its enormously high value is due to the wonderfully minute size of the atoms. Nernst called attention to the relation between this force and the diffusion constant. The force necessary to cause diffusion of salt from a concentrated to a weak solution is found to be of the same order, and practically identical with the force necessary to give the ions their velocity. We can, therefore, conclude that the velocity of diffusion and the velocity of migration of the ions are conditioned by the same kind of internal friction. Nernst has elaborated this remarkable coincidence into a theory of diffusion which has thrown a flood of light on the working of the galvanic cell.

In concluding this condensed account of the most remarkable theory of modern chemical science, I wish to explain, from my own point of view, a conception of the theory which has rendered it much more acceptable to my mind, and quieted some persistent doubts as to the possibility of its truth.

Here I have some potassium, here some chlorine. I bring them together and they unite with tremendous energy. I accept it as an axiom that they cannot be separated again without the expenditure of an equal amount of energy. Yet, along comes an adherent of the dissociation theory, and says: "Dissolve the salt in a large amount of water, and it exists there completely dissociated, not merely into potassium and chlorine molecules, but into potassium and chlorine *atoms*." I confess I am dumbfounded by the assertion. To say that they had been returned to the molecular state, would have been hard to believe; but into the *atoms!* Where does the energy come from to bring the potassium and chlorine back to their elementary state, to say nothing of that required to resolve the potassium and chlorine molecules into atoms? I see no source of such energy. Your statement is incredible, viewed simply from the standpoint of the conservation of energy. To remedy this grave defect in the theory, Ostwald advanced the idea that perhaps the combination of the atoms of an element to form molecules was not such an exothermic operation as we were wont to suppose, but that it must really be a strongly endothermic operation, and that, therefore, the heat *set free* by the *separation* of the potassium and chlorine as *atoms* was the source of the energy necessary to break up the potassium chloride.

I confess that this explanation left matters worse than before. We must assume that potassium atoms unite to form potassium molecules with the *absorption* of a great amount of energy, contrary to every indication which chemistry gives in the opposite direction. If such an assertion can be proven (and there is not a single proof alleged or even possible), we should have to accept it; but it stands at present as a mere gratuitous assumption, contrary to every fact we know, and, therefore, not in any way an acceptable solution of the difficulty.

Quite recently I have come to look at the problem in quite a different way, and have reached the following (to me) satisfactory conceptions. Imagine, if you please, two electro-magnets, as in *Fig. 5*, hanging by their conducting wires 1 foot apart, with their unlike poles, when magnetised, pointing toward each other, as in (I). Pass an electric current through them, and the magnetic pull will bring them, let us say, to within 3 inches, as in (II). Interrupt the current, and the apparatus is ready to illustrate my conception. Bring the magnets to within 3 inches of each other, and hold them there by placing an elastic band around them, as in (III). This physical bond represents the force of chemi-

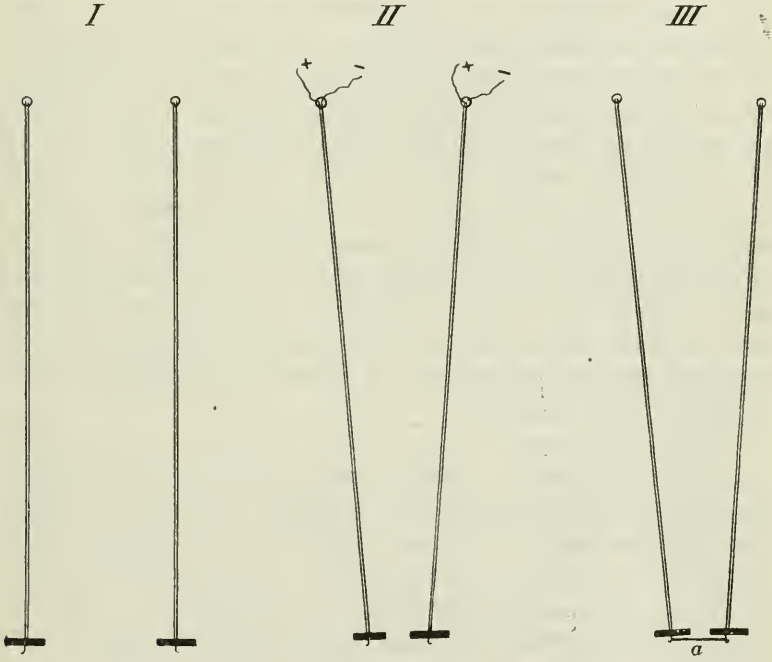


FIG. 5.

cal affinity holding two atoms together in a molecule. Now, at a given instant, *throw off* the rubber band and *throw on* the electric current. If these operations could be performed instantaneously and exactly synchronously, the magnets would remain stationary. The physical bond has disappeared, yet the magnets remain in exactly the same spot as before, held together by the invisible magnetic pull. The disappearance of the physical bond represents, to my mind, the disappearance of the force of chemical affinity holding the atoms together—in other words, what we call the dissociation of the molecule. The atoms are still really united by as great a force after the dissociation as they were before, but it is now electrical force which binds them; our chemical energy has been *replaced* by electrical energy; it is a case of *conversion of energy.* And further, *since the atoms are no longer held together by the force of chemical affinity*, they will be free to act as if *chemically independent* of each other, *i. e.*, as independent atoms or molecules. This will explain the fact of increase of gas pressure, molecular conductivity, and all those properties of solutions which require for their explanation the conception of *chemically independent atoms* present in the solution.

When the atoms are thus held together by *electrical* instead of chemical energy, they are then susceptible of being ultimately separated by a counter *electric* force; and molecules which do not thus dissociate, but are still held together by chemical energy, cannot be disrupted by the current, and are consequently not electrolytes. The law connecting chemical composition with this tendency to "*dissociate*" has not yet been discovered, but when it is brought to light, we shall have a deeper insight into the ultimate nature of chemical combination than has ever before been vouchsafed to the inquiring mind of man.

Stated Meeting, January 21, 1896.

DR. H. F. KELLER, President, in the Chair.

ON THE USE OF ACETONE IN THE TECHNICAL ANALYSIS OF ASPHALTUM.

BY S. F. PECKHAM.

During the month of January, 1894, while in southern California, I had occasion, at the request of lawyers who had charge of several applications for patents then on file in the Patent Office, to seek to distinguish certain residues from the distillation of California petroleum by the use of solvents. A large number were used, and their comparative energy as solvents noted and estimated when applied to the different residues. Among other fluids used were acetone and the most volatile distillates from both Eastern and California petroleums, together with a number of alcohols, etc. The great differences observed in the solubility of the same residuum in these different menstrua led to the use of these different solvents as a means of distinguishing the different residues from one another as different chemical substances, for the reason that Dr. Salathé and myself, who were associated in the work, both believed that solution is in every case a more or less marked example of the action of chemical energy, and is, therefore, properly to be considered a chemical reaction, and an index of chemical properties.

It is, therefore, with no little surprise that I note, in the November number of this *Journal*,[1] a paper by Dr. S. P. Sadtler, in which he advocates the use of acetone as a substitute for petroleum ether in the technical analysis of asphaltum. It is true that my experience had been gained from an examination of artificial residues from natural petroleums, in some instances still further removed from the natural bitumens by further treatment, and it was properly to be inferred that additional testimony should be obtained relative to the comparative solvent action of acetone and petroleum ether upon natural bitumens, before any final conclusions were to be reached relative to the use of acetone as such a substitute. In addition to this consideration is the equally important inquiry concerning the purpose of a technical analysis of asphaltum, and the proper interpretation of the results as heretofore obtained.

---

[1] *Jour. Frank. Inst.*, **140**, 383.

It is true, a great degree of indefiniteness has hovered around the use of the word "petrolene," and, especially, as regards the ultimate composition of the thing itself; but, after the results that have lately been obtained have been properly considered, it cannot be said that the portion of asphaltum soluble in petroleum ether, when ascertained by a careful and skilful manipulator, has any vague significance as a factor in the determination of the relation solid bitumens bear to each other. Not only when applied to different specimens of the same asphaltum, but also when applied to different asphaltums, do the varying proportions of the "petroleum ether soluble" become an indication of varying chemical properties and relations that further investigation respecting ultimate composition will doubtless render more definite, but from which technology need scarcely expect to receive any striking benefit. Moreover, in view of the fact that a large number of determinations are now on record, in which the solvent power of petroleum ether is a fundamental factor, it is quite necessary that, in the selection of any new solvent, an approximate equivalent for petroleum ether should be found; otherwise, both loss and confusion will follow inevitably.

The only object to be sought by a technical analysis of asphaltum is to thereby establish relations along certain lines that are but just beginning to be understood and appreciated. Results lately obtained have given a definiteness and approximate value to such analyses that removes them from the category of mere empirical factors, and places them more nearly in line with those "constants of nature," which are to appear possessed of permanent value.[2]

I was, therefore, led in the light of my former experiences, and also in view of the striking dissimilarity of the results given by Professor Sadtler to any others on record with which I am familiar, to carefully test the use of acetone with petroleum ether in parallel experiments.

Considerably large portions of two samples of pitch, which I had brought from Trinidad, had been dried in my laboratory to a constant weight. One of these specimens (No. 1) was a sample of crude pitch, the other (No. 2) was a sample of Épurée, made on the island. Duplicate and very closely concordant analyses of these samples had been made by the process described by Miss L. A. Linton, in the paper read at the Cleveland meeting of the American Chemical Society.[3] Other portions from the same dried masses of pitch had been weighed for triplicate and quadruplicate analyses, but were not used, as the duplicate analyses were sufficiently concordant. Those weighed portions were used in duplicate to test the comparative solvent power of the acetone, with the following results:

No. 1.

Petroleum ether soluble	33·736	52·367 total bitumen.
Boiling spirits turpentine soluble	10·511	
Chloroform soluble	8·120	
Organic matter not bitumen	10·851	47·580 non-bituminous material.
Inorganic matter	36·729	
	99·937 per cent.	

No. 1.

Acetone soluble	28·180	55·185 total bitumen.
Chloroform soluble	27·005	
Organic matter not bitumen	9·835	44·815 non-bituminous material.
Inorganic matter	34·980	
	100·000 per cent.	

---

[2] *Am. Jour. Science*, to appear.

[3] *Jour. Am. Chem. Soc.*, to appear.

No. 2.

Petroleum ether soluble	33·625	51·875 total bitumen.
Boiling spirits turpentine soluble	15·575	
Chloroform soluble	2·675	
Organic matter not bitumen	10·150	48·125 non-bituminous material.
Inorganic matter	37·975	
	100·000 per cent.	

No. 2.

Acetone soluble	26·310	55·48 total bitumen.
Chloroform soluble	29·170	
Organic matter not bitumen	9·600	44·52 non-bituminous matter.
Inorganic matter	34·920	
	100·000 per cent.	

	No. 1.		No. 2.	
	Petroleum Ether.	*Acetone.*	*Petroleum Ether.*	*Acetone.*
Total bitumen	52·367	55·185	51·875	55·480
Non-bitumen	47·580	44·815	48·125	44·520

From these results it was at once manifest that acetone dissolved much less bitumen than petroleum ether, and, in addition, more than as much more of organic matter not bitumen, and mineral matter. They were also in line with the results given in illustration of his method by Professor Sadtler. In general, Professor Sadtler's results parallel my own, being very low in organic matter not bitumen, and in mineral matter.

To further test this matter, an acetone solution of pitch was prepared and evaporated to dryness at about 60° C. It yielded an organic residuum and deliquescent salt. The salt dissolved away from the bituminous and very viscous residue, and yielded, when evaporated to dryness, an organic residuum soluble in water. A portion of crude Trinidad pitch, exhausted with petroleum ether and chloroform, yielded to acetone a residue, a part of which was soluble in water, a part in sodium hydrate and a part in benzole. One gram of sample No. 1, after exhaustion in chloroform, yielded 1·59 per cent. of material to acetone.

To still further test the relation of the two solvents, equal portions of a very dry Egyptian asphaltum were exhausted under identical conditions with petroleum ether and acetone. The results are given below:

	Per Cent.
Petroleum ether soluble	38·03
Acetone soluble	8·68

Also, an Athabasca River maltha was exhausted in the same manner, with the following results:

	Per Cent.
Petroleum ether soluble	73·863
Acetone soluble	24·333

No difference was observed between the solvent power of cold and boiling acetone in either case. The dry Egyptian asphalt and the semi-fluid maltha exhibit the extremes to which any solvent of bitumen is likely to be applied, and the lack of parallelism is enormously large in both cases.

It appears to me that these results are conclusive, that acetone cannot be made an equivalent for petroleum ether in the technical analysis of asphaltum; first, because its solvent properties are unlike those of petroleum ether when applied to pure bitumen; and second, because it dissolves from a complex mineral, like Trinidad pitch, constituents that are not bitumen, thus defeating the very object of the work itself. According to my own observations, the action of acetone upon bitumens more closely approximates that of the alcohols than that of the true solvents of bitumen. If, therefore, acetone is to be used in the technical analysis of asphaltum, a new series of constants will, of necessity, have to be established, which in my judgment would lead only to confusion.

I am not prepared to judge of the merits of the apparatus suggested in Professor Sadtler's paper. The method by separatory funnels is simple, and capable of yielding results that are all that can be desired.

UNIVERSITY OF MICHIGAN, JANUARY 3, 1896.

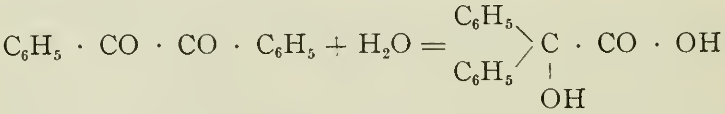
ON THE OXIDATION OF DIACETYL.

BY HARRY F. KELLER AND PHILIP MAAS.

Diacetyl and benzile are the simplest representatives of the class of α-diketones in the fatty and aromatic series, respectively.

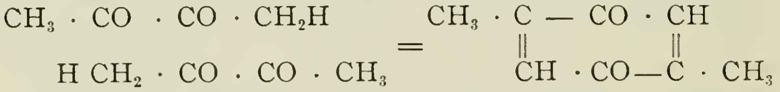
Their constitutions may be regarded as definitely established, since it has been shown that they each contain *two* carbonyl groups, and that these are *directly* united.

But in spite of the close analogy expressed in their formulæ, diacetyl and dibenzoyl show some very remarkable differences in their chemical deportment. In accordance with the general rule, the aromatic compound is distinguished by the greater stability of its molecule. It is true that when treated with alkaline hydroxides, benzile takes up 1 molecule of water, and is transformed by molecular rearrangement into benzilic acid,



$$C_6H_5 \cdot CO \cdot CO \cdot C_6H_5 + H_2O = \begin{matrix}C_6H_5\\ C_6H_5\end{matrix}\!\!>\underset{\underset{OH}{|}}{C} \cdot CO \cdot OH$$

it does not, however, like diacetyl, appear capable of condensing into a quinogen or quinone.



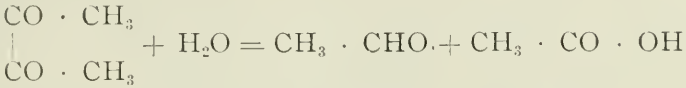
$$\begin{matrix}CH_3 \cdot CO \cdot CO \cdot CH_2H \\ H\,CH_2 \cdot CO \cdot CO \cdot CH_3\end{matrix} = \begin{array}{lcr} CH_3 \cdot C & - CO \cdot & CH \\ \| & & \| \\ CH & \cdot CO - & C \cdot CH_3 \end{array}$$

It is further well known that benzile resists the action of nearly all oxidising agents. Concentrated nitric acid and chlorine, for example, which are used in its preparation from benzoin, appear to be without action upon it. Chromic acid mixture converts it slowly into benzoic acid.

Diacetyl, on the other hand, is quite readily oxidised. The first observation in this direction was made by Fittig and one of us,[1] who found that, under certain conditions, this body reduces silver solutions. To explain this, it was assumed that aldehyde and acetic acid are first formed by hydrolysis.

---

[1] *Annalen*, **249**, 207.



$$\begin{matrix} CO \cdot CH_3 \\ | \\ CO \cdot CH_3 \end{matrix} + H_2O = CH_3 \cdot CHO + CH_3 \cdot CO \cdot OH$$

and the aldehyde further oxidised to acetic acid.

$$CH_3 \cdot CHO + Ag_2O = CH_3 \cdot COOH + 2Ag.$$

From the following experiments it will be seen that the oxidation of diacetyl into acetic acid is readily effected.

Two grams of diacetyl were dissolved in rather more than 25 c.c. of a 3 per cent. solution of hydrogen dioxide, and the mixture heated in a flask provided with an inverted condenser. Color and odor of the diketone soon disappeared, while the liquid acquired a strongly acid reaction. An excess of barium carbonate was now added, and, after warming for some time, the solution filtered off. The filtrate was evaporated to a small volume and then allowed to stand in a desiccator over sulphuric acid. At first, long needle-like crystals radiating from a common center separated, and, after evaporation to dryness, a crystalline mass weighing 6·2 grams remained. This is nearly the theoretical quantity—6·34 grams—required for $Ba(C_2H_3O_2) + H_2O$.

The salt gave all the reactions peculiar to acetates. Warmed with concentrated sulphuric acid, it emitted pungent fumes, and with alcohol and sulphuric acid, the fragrant odor of acetic ether. Ferric chloride produced a blood-red color in the aqueous solution.

The greater part of the barium salt was dissolved in water and precipitated with silver nitrate. Recrystallised from hot water, the silver salt formed the characteristic shining and flexible needles, darkening when exposed to daylight. It was analysed with the following results.

I. ·6075 gram yielded ·3919 gram metallic silver.
II. ·7234 " " ·4671 " " "

	Calculated for:	Found:	
	$Ag.C_2H_3O_2$	I.	II.
Ag	64·59 per cent.	64·51 per cent.	64·57 per cent.

Hence, it follows that hydrogen dioxide quantitatively converts diacetyl into acetic acid.

Permanganic acid acts on diacetyl in an analogous manner. When a solution of potassium permanganate is added to diacetyl dissolved in water and acidified with sulphuric acid, the purple color is instantly discharged.

·5341 gram of the diketone was dissolved in water and sulphuric acid added: 92 c.c. of a permanganate solution of the standard 1 c.c. = ·0058 Fe., were decolorised by this liquid. This represents ·077 gram of oxygen, while theory would require ·098 gram.

In another experiment 3 grams of diacetyl were taken and 64 c.c. of a 2·5 per cent. solution of permanganate run in. This would correspond to ·405 gram of oxygen, instead of ·55 gram calculated.

That acetic acid is actually the main product of this oxidation, was proved by distilling the solution which resulted from the last experiment. By neutralising the distillate with barium carbonate, filtering and evaporating, about 4·5 grams of the acetate were obtained. It was tested in the manner already described.

Numerous experiments were made with nitric acid as the oxidising agent.

Having observed that, when highly concentrated, this acid acts upon diacetyl, even at ordinary temperatures, with formation of oxalic acid, we hoped to obtain intermediate products, perhaps ketonic acids, by working at low temperatures, and by diluting the nitric acid. These expectations have not been realised.

Five grams of diacetyl were mixed with nitric acid, specific gravity 1·48, in considerable excess. The temperature slowly rose to about 50°, when the action became exceedingly violent, torrents of red vapors being emitted. After the reaction ceased, the residue was dissolved in warm water; upon standing, a few tabular, rhombus-shaped crystals deposited. A larger crop of prismatic crystals formed after concentrating the solution, and these were easily recognised as oxalic acid. They melted at 100·5°, and their aqueous solution was precipitated by calcium chloride and silver nitrate. Weighed portions of the crystals required the same quantities of standard solutions of caustic potash and permanganate as the same amounts of pure oxalic acid.

We are, at present, unable to say whether or not the tabular crystals first obtained were oxalic acid. Their total amount was less than a decigram. They blackened on heating, and repeated determinations of the melting point gave 128°. A weighed quantity was neutralised by one-fifth less of standard alkali than the same weight of oxalic acid. Otherwise, the reactions were like those of the latter acid.

In a second experiment, 2 grams of diacetyl were carefully poured on top of the nitric acid, so that the liquids could mix only by diffusion. The vessel was placed in cold water. After two weeks, the odor of diacetyl had disappeared, and the liquid was full of flat, prismatic crystals, which proved to be pure oxalic acid.

Ordinary nitric acid acts but slowly in the cold. At 50° to 60° the reaction becomes very violent, the sole product being oxalic acid. Similar observations were made when an acid diluted with its own volume of water was employed.[2]

[ABSTRACT.]

A FERRUGINISED TREE.

By Oscar C. S. Carter.

On the farm of Wm. Teas, situated about a mile from Three Tuns, Montgomery County, Pa., is a quarry of loose, disintegrating sandstone, of a light-yellow color. The first few feet of the surface is made up of loose sand, resulting from the decomposition of the underlying sandstone. Below the sand is the crumbling sandstone rock. This rock is made up of grains of sand bound together with a cement of feldspar. The feldspar is chalky-white in appearance, and is decomposing, which accounts for the crumbling nature of the sandstone. Soils derived from sandstone rocks of this nature are loose and porous, permitting moisture, air and heat, to act on the roots of growing crops, and yet the feldspar yields enough clay to hold a certain amount of moisture, and to prevent the soluble fertiliser from draining away too rapidly. Then, again, the feldspathic cement contains potash, which is a valuable plant food. This cement of feldspar is characteristic of certain tracts of sandstone in parts of the New Red belt of Montgomery County. A piece of this rock will generally show the chalky-white, decomposing feldspar, and the resulting soils are fertile. While digging sand some time ago, Mr. Teas came across what seemed to be a mass of iron ore, from 6 to 10 inches in diameter, and about 15 feet long. It was found about 10 feet below the surface, in the sand, and only a few inches above the solid rock. This mass of ore had the exact outlines of the lower part of a tree. On loosening the mass from the crumbling sandstone, it was broken. A close examination showed that it was a tree that had been ferruginised, or pseudomorphosed into iron ore. The bottom of the log was harder than the top, as it was found in the quarry. The rough outside bark could be clearly distinguished, and on one piece a knot was observed, which was entirely converted into iron ore.

---

[2] Fileti and Ponzio (*Gazz. chim. ital.*, **25**, 233), in a paper on the oxidation of ketones, state that methyl-ethyl ketone, by warming with nitric acid, specific gravity 1·38, is converted into diacetyl. They also observed the destruction of this diketone by nitric acid, but do not appear to have examined the products.

One fact, which settles beyond all doubt that it was part of a tree, is that some parts of the trunk are not entirely converted into iron ore, but still show their woody texture. These parts are partially carbonised, and make a black streak on paper like charcoal. This part of the tree is an imperfect lignite.

The ore is the hydrated oxide of iron, known as brown hematite ($2Fe_2O_3 . 3H_2O$). In one or two places spots of yellow ochre are noticed, and, in one specimen, was noticed a little red ochre. Here and there, on some of the specimens, were noticed patches of the peculiar iridescent hematite. The great mass of the ore, however, was brown hematite. It is unusual to find masses of brown hematite in this sandstone of Mesozoic Age, although the coloring matter of our Montgomery County sandstones and red shales is due to red and brown hematite. The red shales often hold as high as 7 per cent. of iron; one specimen from near Norristown, on the Stony Creek Railroad, which I analysed, contained 10 per cent. of ferric oxide. No workable beds of iron ore have ever been found in the sandstone of Montgomery County. The iron ore in this county is found in the clay and limestone and hydro-mica schist. * * *

The soil and rocks of this quarry and vicinity once contained enough iron to give them a distinct red color. As the rainwater gradually drained through the soil it finally removed the iron from the soil and rocks in the form of carbonate, and the color of the sandstone changed from red to light yellow. It is well known that if a fragment of wood or charcoal be placed in a chalybeate water the iron will be precipitated as hydrate. Therefore, when this water, charged with iron, came in contact with the tree, there took place an interchange of particles, the woody matter being replaced by the iron.

It is to be regretted that the entire tree was not safely removed from the sandstone and preserved, as finds of this kind are rare in the New Red sandstone. Good specimens, however, were obtained.

The influence of the reducing action of organic matter on the red coloring matter of soils and rocks is often noticed. On the country road between Eagleville and Arcola, there is a red and white sandstone containing irregular black patches of organic matter. On splitting the rock, layer after layer of this black carbonaceous matter is seen. The sandstone is only white where in contact with, or near to, the organic matter; the rest of the rock is red. The red coloring matter of the sandstone is due to red hematite. Water containing carbonic acid filtering through the bed planes, had dissolved the ferrous oxide, formed by the reducing action of the carbonaceous matter, and thus leached out the red coloring matter of the sandstone, leaving it white. Precisely the same kind of rock as the above was noticed in the New Red in a quarry near Three Tuns, not very far from where the iron tree was found.

DEPARTMENT OF GEOLOGY AND MINERALOGY,
CENTRAL HIGH SCHOOL,
PHILADELPHIA, JANUARY 21, 1896.

NOTES AND COMMENTS.*

REPORT OF THE NICARAGUA CANAL COMMISSION.

The New York *Herald* of recent date publishes what is declared to be a full abstract of the conclusions of the Commission of Engineers appointed by Congress to investigate the plans and estimates of the Nicaragua Canal Company.

If this account is to be credited, the report of the Commission casts grave doubt, not to say discredit, on the enterprise.

The *Herald's* account states that the Commission finds that the preliminary engineering has been so very imperfectly done as to leave the question of the feasibility of the plans proposed open to serious doubt, and that the data accessible do not justify the estimates of cost. The Commission doubles the estimates of the Company, making the figures $133,472,893, as compared with $69,893,660, the figures named by the promoters.

Among other things, the Commission recommends to Congress that $350,000 be appropriated to defray the expenses of additional preliminary engineering work, which is held to be necessary before the data will be accessible upon which to base a safe estimate of the cost of the canal. W.

THE INCANDESCENT ELECTRIC LAMP DECIDED TO BE EDISON'S INVENTION.

A recent decision of the Supreme Court of the United States (read by Justice Brown) sustained the Edison patent for the incandescent electric lamp, against the claim of the Consolidated Electric Light Company, representing the Sawyer-Mann patent.

The first point on which the decision was based related to an informality in the manner in which the Sawyer-Mann application was made; this being simply a legal technicality, it has no interest for us.

The second point related to the nature of the filament, and, in the opinion of the Court, Sawyer and Mann were not successful in finding a proper material for the purpose. Their claim "of a conductor composed of carbonised and fibrous material," the Court held, "is too broad to sustain the patent, and must, therefore, be declared invalid. They could not, by such a claim, shut out all other investigators into the field of vegetable fibre. * * *" After examining some 6,000 different materials, Edison finally adopted bamboo as the best material, and it appeared that Sawyer and Mann had abandoned the materials they had used in their early experiments and adopted the material used by Edison.

The judgment of the Court below, declaring the Sawyer-Mann patent to be invalid, is for these reasons affirmed. W.

---

* Chiefly from the Secretary's monthly reports.

GROWTH OF THE ALUMINUM INDUSTRY.

The efficiency of the electro-metallurgical methods now exclusively employed in the production of aluminum, is strikingly shown by the figures of the following tabulation, representing the product of the United States since 1882. The first impetus to the industry was given in 1886, when the electric furnace plant of the Cowles brothers was fairly put in operation. In 1889, when the Pittsburgh Reduction Company entered the field with the Hall electrolytic process, another great advance in output was recorded; and the industry has since been steadily growing year after year.

Year.	*Pounds.*	*Year.*	*Pounds.*
1883	83	1889	47,468
1884	150	1890	61,281
1885	263	1891	150,050
1886	3,000	1892	259,885
1887	18,000	1893	339,629
1888	19,000	1894	550,000

The *Iron Age* estimates the American output of aluminum, in 1895, at 850,000 pounds, and believes that the production of the present year will reach the imposing total of 6,000 pounds per day, or over 2,000,000 pounds.

W.

PRODUCTION OF BESSEMER STEEL INGOTS AND RAILS IN THE UNITED STATES IN 1895.

Mr. James M. Swank has just published, in the *Bulletin* of the American Iron and Steel Association, the complete statistics for the year 1895, of the production of Bessemer steel ingots and Bessemer steel rails of all weights and sections, in the United States, except the comparatively small quantity of standard rails, and a larger quantity of street rails which were made by manufacturers from purchased blooms. In the statistics of ingots produced are included the production of the few Clapp-Griffiths and Robert-Bessemer plants, and also the production of steel castings by all Bessemer works.

"*Ingots.*—The total production of Bessemer steel ingots in 1895 was 4,909,128 gross tons, against 3,571,313 gross tons in 1894, showing an increase in 1895 of 1,337,815 tons, or over 37 per cent. The production in 1895 was much the largest in our Bessemer steel history. The following table gives our production of Bessemer steel ingots in the last ten years:

Years.	*Bessemer.*	*Years.*	*Bessemer.*
Gross Tons.	*Ingots.*	*Gross Tons.*	*Ingots.*
1886	1,269,190	1891	3,247,417
1887	2,936,033	1892	4,168,435
1888	2,511,161	1893	3,215,686
1889	2,930,204	1894	3,571,313
1890	3,688,871	1895	4,909,128

"With an estimated production in 1895 of over 1,000,000 tons of open-hearth steel, soon to be accurately ascertained, it is probable that our total production of steel in that year exceeded 6,000,000 tons. Great Britain's total steel production has never amounted to 4,000,000 tons in any year.

"The following table gives the production of Bessemer steel ingots by States in 1892, 1893, 1894 and 1895:

Ingots. *States.*	*1892.* *Gross Tons.*	*1893.* *Gross Tons.*	*1894.* *Gross Tons.*	*1895.* *Gross Tons.*
Pennsylvania	2,397,984	2,126,220	2,334,548	2,978,924
Illinois	879,952	314,829	581.540	866,531
Ohio	409,855	348,141	363,974	719.954
Other States	480,644	426,496	291,251	343 719
Total	4,168,435	3,215,686	3,571,313	4,909,128

"*Rails.*—The production of all kinds of Bessemer steel rails by the producers of Bessemer steel ingots in 1895 was 1,266,081 tons, against a similar production of 904,020 tons in 1894, 1,036,353 tons in 1893, and 1,458,732 tons in 1892. The following table shows the production by States of Bessemer steel rails by the producers of Bessemer steel ingots in 1892, 1893, 1894 and 1895:

Rails. *States.*	*1892.* *Gross Tons.*	*1893.* *Gross Tons.*	*1894.* *Gross Tons.*	*1895.* *Gross Tons.*
Pennsylvania	885,652	639,431	606,866	837.043
Illinois	450,542	232,260	225,869	324,050
Other States	122,538	164,662	71,285	104,988
Total	1,458,732	1,036,353	904,020	1,266,081

"When we shall have received the returns of the production of Bessemer steel rails from purchased blooms in 1895, it is probable that the total production of Bessemer steel rails in that year will be found to have exceeded 1,350,000 gross tons."

MEDICAL APPLICATIONS OF RÖNTGEN'S DISCOVERY.

From London *Nature*, we learn that the new photography has received the official recognition which is usually given to scientific discovery in Germany. Professor Röntgen has been honored by the Emperor, and the Prussian Minister of War has caused experiments to be made in order to discover whether the method can be applied successfully to army surgery. A series of photographs of bone injuries have shown so clearly the nature of the wounds and the position of imbedded projectiles that it has been determined to carry on the experiments on a larger scale.

"Medical science seems likely to benefit much by the application of Professor Röntgen's discovery. The *British Medical Journal* thinks, as an aid to diagnosis of obscure fractures and internal lesions generally, the new photography will be of great value. From our contemporary we note that already a beginning has been made in this direction, and Professor Mosetig, of Vienna, has taken photographs which showed, with the greatest clearness and precision, the injuries caused by a revolver-shot in the left hand of a man, and the position of the small projectile. In another case, the same observer detected the position and nature of a malformation in the left foot of a girl with entire success. Professor Lannelongue, of Paris, has also been successful in photographing some of his cases in his ward at the Trousseau

Hospital, and, assisted by MM. Oudin and Barthélemy, has submitted to the Academy of Sciences several negatives of human limbs. One of them represented a diseased thigh bone. The destroyed central portions had been penetrated by the light, forming white blotches on the plate. Another photograph was that of a tuberculous affection of the bone in a child's hand. The disease had been diagnosed, but photography brought complete confirmation to the diagnosis.

"The Berlin correspondent of the *Lancet*, referring to the practical use being made of the discovery, says in one case a finger which had sustained a compound fracture, and from which a sequestrum had been removed, was photographed by the new process, and the regeneration of the bone was thereby made visible. In another case, the position of a piece of glass embedded in the tissues was ascertained by the same method. Similar reports come from other universities, as, for instance, from Berne, where Professor Kocher has photographed a needle in a woman's hand; it had made its way under the skin some time ago, and had not been found by any other means."

In the United States, also, many accounts have appeared in the public prints relating similar successes in the application of the new photography to the diagnosis of obscure cases requiring surgical treatment, and it appears most probable that in this field the new method will yield results of much practical value. W.

ENGINEERING TOOLS AT POMPEII.

Under the title of "Things of Engineering Interest Found at Pompeii," Professor Goodman lately gave his inaugural lecture in the engineering department of the Yorkshire College, Leeds, the following abstract of which is gleaned from the *Scientific American* :

The lecturer remarked that he had recently visited Pompeii, and was not only charmed by the great beauty of the works of the ancient Romans, but also by their extreme ingenuity as mechanics—in fact, it was a marvel how some of the instruments and tools they were in the habit of using could possibly have been made without such machinery as we now possess.

After explaining the situation and destruction of Pompeii by showers of ashes and mud—not lava, as is usually supposed—in the year 79 A.D., Professor Goodman showed a series of about fifty lantern slides, prepared from photographs taken by himself in Pompeii last Easter. The streets, he explained, were used as waterways to carry off the surface water, and probably sewage, from the houses. The pavements were raised about a foot above the streets, and stepping stones were provided at intervals for foot passengers.

The horses and chariot wheels had to pass between, and in many places deep ruts have been worn by the chariot wheels in the stone-paved streets. The water supply of Pompeii was distributed by means of lead pipes laid under the streets. There were many public drinking fountains, and most of the large houses were provided with fountains, many of most beautiful design. The amphitheater, although a fine structure, capable of seating 15,500 people, was small compared with many in Italy. The bronzes found at Pompeii reveal great skill and artistic talent. The bronze brazier and kitchener were provided with boilers at the side and taps for running off the hot water. Ewers and urns have been discovered with internal tubes and furnaces precisely similar to the arrangement now used in modern steam boilers. Several very strong metal safes, provided with substantial locks, have been found. The locks and keys were most ingenious, and some very complex. On looking at the iron tools found in Pompeii, one could almost imagine he was gazing into a modern tool shop, except for the fact that the ancient representatives have suffered severely from rust.

Sickles, billhooks, rakes, forks, axes, spades, blacksmiths' tongs, hammers, soldering irons, planes, shovels, etc., are remarkably like those used to-day; but certainly the most marvellous instruments found are the surgical instruments, beautifully executed, and of design exactly similar to some recently patented and re-invented. Incredible as it may appear, yet it is a fact that the Pompeiians had wire ropes of perfect construction.

A CURIOUS OCCURRENCE OF VANADIUM AND PLATINUM.

The *Engineering and Mining Journal* makes the statement, on the authority of "a reliable correspondent," that a firm of merchants in London, are in possession of some extensive deposits of coal, the ash of which contains considerable quantities of vanadium and the platinum metals. The coal yields 15 per cent. of ash, which gave, on analysis, 2·9 per cent. of vanadium, 0·23 per cent. of platinum metals (chiefly platinum). From these figures, it will be noticed that the metallic contents of 1 ton of the coal would be 141 ounces of vanadium and 11·24 ounces of platinum metals.

The value of this deposit, assuming that it is, as claimed, "very extensive and of fairly uniform contents," may be estimated from the fact that the present value of vanadium is from $40 to $45 per ounce (troy), and that of platinum, $13.50 to $14 per ounce.

If large quantities of vanadium could be supplied at low price, there would probably be a considerable demand for it, for the manufacture of vanadium black.

The exact location of this interesting deposit is, for obvious reasons, not disclosed, but it is believed to be in the province of Mendoza, in Argentina.

W.

ENGINEERING NOTES.

In connection with the *natural gas supply* in Western Pennsylvania, the following item from the *Iron Age* will be of interest, viz.:

The Philadelphia Natural Gas Company, of Pittsburgh, has a larger supply of gas for their private customers than at any time within the past three years. In fact, the concern has more gas than its private consumers can use, and recently mailed to Pittsburgh manufacturers copies of a circular in which the following prices are quoted: For the first 500,000 cubic feet, or part thereof, consumed per month, 15 cents per 1,000; for the second 500,000 cubic feet, or part thereof, consumed per month, 10 cents per 1,000; for all over 1,000,000 cubic feet consumed per month, 8 cents per 1,000, subject to the conditions of the regular form of contract.

The New York *Herald's* forecast of the report of the commission of engineers appointed to investigate the *Nicaragua Canal*, of which a brief statement appears in this impression of the *Journal*, proves to have been strictly correct. The outcome of this investigation, by a body of professional experts of the highest standing, is practically to double the estimate of cost made by the promoters, making it $133.472,893 instead of $69,893,660.

Proposals have been called for on the enlargement of the wheelpit of the *Niagara Falls Power Company*, to provide for three additional dynamos and turbines, to furnish 15,000 horse-power additional power for local use. The Acetylene Gas Company is reported to have closed a contract with the Power Company for 10,000 horse-power. Work on the Canadian power plant is also to be pushed.

M. Roger, the inventor and manufacturer of automobile carriages, has made application to the police authorities of Paris for permits to run a number of *horseless carriages* on the streets, for hire at the regular legal rate of 30 cents a drive, or 40 cents an hour when hired on the street. When hired from a cab-stand the charge is slightly greater. It would appear from this that the problem of operating such vehicles cheaply enough to compete with the regular "fiacres" has been solved.

The *Railroad Gazette* reports the construction, in 1895, of 31,893 *freight cars* in the United States, as compared with 17,029 built in 1894. This is an improvement, and indicates that the turn of the tide has come; but when the figures are compared with those of the years immediately preceding (51,000 in 1893, and 93,000 in 1892), it is seen that, to restore the industry to its normal condition, a substantial increase is still needed.

Electric street car companies in Tacoma, Wash., are to be required to repair all *damages to water pibes caused by electrolysis*. In repairing one of the principal avenues of the city, along which runs an electric car line, it was found that more than one-half of the surface and connecting pipes, running from the water main to buildings, had been so eaten away by the electric current grounded through the rails as to be useless. The pipes were replaced by the city at a cost of more than $1,000. All franchises hereafter granted will contain a clause that the company shall repair damage thus caused. W.

TECHNICAL NOTES.

A New Heavy Liquid for Mineral Determinations, proposed by Penfield, is prepared by mixing equal proportions of silver and thallium nitrate. This mixture fuses at 75° C., forming a clear mobile liquid, having a density of 4·5, and which mixes with water in all proportions. It can, therefore, be used to separate minerals having densities below 4·5, from those which are lighter. London *Nature* gives the following further details:

"When still heavier particles have to be separated, the proportion of thallium may be increased. When the ratio is 3 : 4 the mixture fuses below 100° C., and has a density of about 4·7. At 2 : 4 the fusing point becomes 150° C., and the density 4·8; at 1 : 4 it is about 4·9, and fusion only takes place at 200°. Finally, when pure thallium nitrate is used, the point of fusion is 250° C., and the density closely approaches 5. This high range of densities, together with the fact that the salts do not attack many minerals, make the liquid especially valuable for mineralogical purposes. A convenient separator is described by the same author. It consists of a thimble-shaped cup, into which a wide tube is made to fit. The tube can be closed at the bottom by a hollow plug. This plug being removed, the heavy liquid is poured through the tube into the thimble, and the minerals are thrown in and stirred. The heavy particles sink into the thimble, and may be removed by closing the tube with the plug and withdrawing the thimble. The latter is then replaced, and the operation repeated with dilute liquid. With some practice an elaborate separation by densities is rapidly and easily accompliished."

Anthion is the commercial name under which a new and powerful oxidising agent is placed upon the market by the manufacturers, the *Chemische Fabrik*, of Berlin.

It is potassium persulphate, formed by the electrolysis of an aqueous solution of the sulphate. The persulphate is precipitated about the anode, and may be separated and purified by re-crystallisation from its solution in warm water.

It is said to be employed advantageously in dyeing and bleaching, but its greatest utility is found in photography, where it is applied successfully for the removal of the last traces of hypo from photographic prints. These residual traces of the hypo used in fixing the photographic image, which resist removal even after prolonged washing—and which are held to be responsible for the gradual deterioration of photographic prints—are said to be completely removed by the oxidising action of the persulphate.

Sodium as an Impurity in Commercial Aluminum has been found by Moissan to be present in the electrolytic aluminum produced at La Praz (France), Neuhausen (Switzerland) and Pittsburgh (U. S.), in quantities varying from 0·1 to 0·3 per cent. He finds that the presence of this small quantity of sodium renders the metal liable to be slowly attacked by water, and also decidedly alters the character of alloys of aluminum. He attributes to this cause certain discrepancies in the results of various investigators respecting some of the properties of aluminum.

An ink for *writing on glass*, as with ordinary ink, is made, according to the *Microscope*, of bleached shellac, 10 parts; Venice turpentine, 5 parts; lampblack, 5 parts. The ingredients are commingled and thinned down to the proper consistency with spirits of turpentine.

BOOK NOTICES.

National Car and Locomotive Builder; American Engineer and Railroad Journal.

The above-named technical journals have been consolidated, and, beginning with the impression for January, 1896, are now published monthly, under the title of *American Engineer, Car-Builder and Railroad Journal.* The editorial department will be under the supervision of Mr. M. N. Forney, assisted by Mr. Waldo H. Marshall. W.

Sixteenth Annual Report of the United States Geological Survey to the Secretary of the Interior, 1894-1895. Charles D. Wolcott, Director. Part III. Mineral Resources of the United States, 1894; Metallic Products. David T. Day, Chief of Division. Washington: Government Print, 1895.

The work above entitled forms an imposing royal 8vo of some 650 pages, and deals apparently in an exhaustive way with the metal industries of the United States. The several divisions of the subject have been entrusted to well-known experts, whose names are in most cases a sufficient warranty for the value of their respective contributions. Among those we need only name Birkinbine (iron ores), Swank (iron and steel), Kirchhoff (copper, lead, zinc), Weeks (manganese), Rölker (tin), Garrison (chromium, tungsten).

The delay in the appearance of this volume, which seems to be unavoidable in the issue of public documents, naturally detracts somewhat from its interest, but nothing whatever from its permanent value as a work of reference.

The departure taken in the change of form to that of the royal octavo makes the publication conform with the annual reports of the Survey, of which it forms a part, and is a decided improvement.

It may interest our readers to know that the cost of printing and binding is no longer charged for this book, and that by making prompt application to a Senator or Representative the volume may be obtained without cost.

W.

The Lehigh University School of Mechanical Engineering, under the direction of Prof. J. F. Klein. Bethlehem, Pa.

We have received from the head of this department a pamphlet descriptive of the course and methods of study pursued in the School of Mechanical Engineering. From an examination of this circular—which gives much fuller details as to the kind of work done and the methods of instruction than one is accustomed to find in a college publication—it would appear that, in respect of both, this progressive institution affords exceptionally good facilities for students ambitious to qualify themselves for the profession of the mechanical engineer. The course appears to combine, in a judicious manner, theory with practice; and the location of the University, at South Bethlehem, Pa., in the midst of a number of the largest industrial establishments in the country, to which the students have free access for observation and study, is an advantage which will be duly appreciated.

The technological courses of the Lehigh University embrace the following departments: (1) Civil Engineering; (2) Mechanical Engineering; (3) Mining Engineering and Metallurgy; (4) Electrical Engineering; (5) Analytical Chemistry; (6) Architecture. The pamphlet of the Mechanical Engineering course, here referred to, is the first of a series, which will be followed by similar publications descriptive of the other departments. W.

Practical Work on General Physics, for use in schools and colleges. By W. G. Woolcombe, M.A., B.Sc., etc. Printed at the Clarendon Press. New York: Macmillan & Co. 1894. Price, 75 cents.

This work is designed as a manual for the student to familiarise him with the apparatus and methods of experimental work. There has been a radical change within the past decade or two in the methods of instruction in science, growing out of the better appreciation of the fact, that experimental work must go hand-in-hand with book or lecture instruction if the student is to reap the full benefit of his scientific studies. The present book is one of a number of such practical guides to experimental work, which have been prepared in answer to the needs of schools where physical science is taught. It is well arranged for its intended purpose, and will be found useful where a graded course of elementary physical experimentation is desired. W.

Quarterly Digest of Physical Tests and Laboratory Practice. A *résumé* of practical tests made in the laboratories of the world. Philadelphia: Riehlé Bros. Testing Machine Company, Proprietors and Publishers. Vol. 1., January, 1896, No. 1. Price, $1 per year. Single numbers, 30 cents.

This periodical, of which the initial impression has just appeared, is designed to cover a field which has not yet been exclusively appropriated by any other technical publication in this country. If it shall adequately meet the possibilities of its title it will prove of the greatest service to the engineering profession. The contents of the first impression embrace a number of original contributions by well-known writers, and numerous useful abstracts. The new journal appears in magazine form, an 8vo of 86 pages, well printed and liberally illustrated. W.

The Elementary Principles of Mechanics. Vol. I, Kinematics. By A. Jay DuBois, C.E., Ph.D. New York: John Wiley & Sons, 1894. Pp. x, 231.

This work is the first of a series, the other two being called Statics and Kinetics. This first volume is divided into four general divisions: an Introduction of 14 pages; the General Principles of Kinematics, 76 pages; Kinematics of a Point, 78 pages; and Kinematics of a Rigid System, 63 pages. In the body of the work a difference in type enables one to separate what might constitute an abridged course from articles intended for advanced students, while those articles containing applications of the calculus are enclosed in brackets.

It is doubtful whether a work of this kind is of any value to students who are not fairly familiar with the principles of calculus. The number of formulæ, some of them quite intricate, which are expected to be handled in the abridged portion of the work would seem to indicate that a high grade of mathematical knowledge should be possessed by the student before beginning the subject. In a subject as important as the one here treated of the calculus preparation should always be required if the matter is to be properly presented in the time which should be allotted to it in an engineering course.

The "Introduction" covers the definition of the units the author intends using, and what are called dimensional equations, together with definitions of such terms as "rigid system," "motion of translation," etc.

The part treating of "General Principles" is subdivided into speed, rate of change of speed, displacement, velocity, acceleration, moments, angular revolution and differential equations. It is interesting to note the continual use of dimensional equations, which have no more to do with mechanics than with any other exact science, and which add to the learned look of the printed page without, in the slightest, adding to the clearness.

The author continues the physicist's contention, that it is desirable to make sufficient distinction between speed and velocity, to repeat the same equations and almost exactly the same wording while dealing with each. It is easy to understand that the difference he makes he considers essential; but on page 43 he states that "it follows that the unit of velocity is the same as the unit of speed;" and on page 51, "all of the equations are precisely similar to those on page 28, except that we have f in place of a;" "these," referring to equations of motion in the chapter on acceleration, and "those," to similar equations in the chapter on rate of change of speed.

It is interesting to note that the use of the term "speed" as the unit of velocity is marked (Rare) in the Standard Dictionary, and it is to be hoped that it will soon be marked (Obs).

That portion of the work treating of "Kinematics of a Point" is subdivided into rectilinear motion, translation in a curved path, and constrained motion.

The ground is covered completely, using freely the calculus, and in many instances dropping away from the mathematical formulæ, and deducing the results desired by a clear course of reasoning which is very satisfactory. There is one problem which is sure to attract any one casually looking over the book. It is a selection from "Hiawatha," where his fleetness of foot is extolled, and the author supposing that an arrow is shot every second, aimed so that its range is greatest, concludes that about 99 miles per hour was his speed.

The last section of the text is subdivided into rotation, translation and rotation, and a general analytic analysis of a rigid rotating system.

Chapter I treats of rigid system with one point fixed, and seems to be entirely unnecessary, and the entire chapter could be replaced by a single paragraph, showing that what has already been proved relating to the movement of one point about another fixed point, exactly covers all the conditions which might be imposed on the rigid system here, discussed.

Chapter II treats generally of combination of non-concurring angular velocities, and the special case of rotation and rectilinear translation combined. The treatment is satisfactory from a mathematical standpoint, but an examination of the problems at the end of the section shows that the greater part of them could have been solved with only a common-sense application of the elementary ideas on which the chapter is founded. One of the very good features of the book is the large number of examples at the end of each subdivision of the subject. One of the unfortunate things is that a comparatively few pages would cover all the knowledge of mechanics, and a little common-sense and few intricate mathematical formulæ would be sufficient to apply the little knowledge of mathematics to the successful solution of most of them. H. W. S.

Franklin Institute.

[*Proceedings of the stated meeting, held Wednesday, February 19, 1896.*]

HALL OF THE FRANKLIN INSTITUTE,
PHILADELPHIA, February 19, 1896.

MR. JOSEPH M. WILSON, President, in the chair.

Present, about 400 members and visitors.

Additions to membership since last report 12.

The Board of Managers, to which had been referred the question of permitting members to vote at the annual election by letter-ballot, reported that it was inexpedient to make the change proposed.

Drs. Edwin J. Houston and A. E. Kennelly presented a joint paper entitled "A Communication Concerning the Röntgen Rays." The paper was a historical *résumé* of the subject, with critical considerations respecting the recent developments of Röntgen's investigation. The authors illustrated their paper by the exhibition of the apparatus employed in photography with the X rays, and of a large number of prints and lantern slides of such photographs.

The discussion of the paper was opened by Dr. Kennelly, who was followed by Prof. A. E. Dolbear, Prof. Elihu Thomson, Dr. Jos. W. Richards, Prof. Charles F. Himes, Prof. Geo. A. Hoagley, Mr. W. N. Jennings, Mr. John Carbutt, Mr. James Wilson, Mr. A. E. Outerbridge, Jr., Prof. M. B. Snyder, Mr. Charles Richardson, Mr. E. G. Willyoung, Prof. L. F. Rondinella, Prof. Geo. F. Stradling, and others. The discussion was closed by Dr. Kennelly, who moved that the thanks of the Franklin Institute be transmitted to Prof-Dr. Röntgen, of Wurzberg, for his important contribution to science in investigating the properties of the X rays. The motion was numerously seconded, and, on being put to vote, was unanimously adopted.

The paper of Drs. Houston and Kennelly, with the discussion thereon, will be printed in the *Journal*.

Adjourned.

WM. H. WAHL, *Secretary*.

JOURNAL

OF THE

FRANKLIN INSTITUTE

OF THE STATE OF PENNSYLVANIA,

FOR THE PROMOTION OF THE MECHANIC ARTS.

VOL. CXLI. APRIL, 1896. NO. 4

THE Franklin Institute is not responsible for the statements and opinions advanced by contributors to the *Journal*.

THE FRANKLIN INSTITUTE.

Stated Meeting, held Wednesday, February 19, 1896.

JOS. M. WILSON, President, in the chair.

THE RÖNTGEN RAYS.

BY EDWIN J. HOUSTON, PH.D., AND A. E. KENNELLY, SC.D.

The announcement of a scientific discovery has seldom produced so intense an excitement throughout the civilised world as has that made in December last, by Professor W. C. Röntgen, of Wurzburg, Bavaria, concerning his ability to obtain a photograph of the bones of an animal through its living integument. His announcement, indeed, has created so intense an excitement and enthusiasm, that, although the discovery is practically only a few weeks old, yet his experiments have been repeated in all parts of the world.

The authors have been requested, by the Franklin Institute, to present to its members a *résumé* of the facts that are known concerning Röntgen's discovery, as well as of some of the theoretical explanations which have been offered in connection therewith.

The paper in which Professor Röntgen announced his discovery was addressed to the Wurzburg Physico-Medical Society in December last.

Professor Röntgen describes in this paper the method he adopted for obtaining the peculiar form of radiant energy, now generally known as the Röntgen rays, and for which he proposed the provisional name of X rays. On passing the discharge from a large Ruhmkorff coil through a suitably exhausted tube of the Hittorf, Lenard, or Crookes type, a peculiar effect, invisible to the eye, is produced in the region outside the tube. This effect, however, can be rendered visible by the fluorescence excited in a paper screen, painted with a solution of barium-platino-cyanide. In vacuum tubes of the type referred to, the passage of the proper discharge is attended by the production of rays, called cathode rays; that is, rays projected in straight lines from the cathode, or negative electrode, of the vacuum tube.

It was observed by Crookes that these cathode rays were not produced to an appreciable degree until a certain high vacuum was reached. Crookes showed, by his experiments that, in so high a vacuum, matter could be regarded as existing in a fourth state or condition, to which he gave the name of the *radiant* or *ultra-gaseous state*. The highly rarefied matter contained in these vacua is capable of producing characteristic effects when subjected to heat or electrification. For example, when an electric discharge is passed through the residual atmosphere in the tubes, the molecules are shot off in rectilinear paths from the cathode, and wherever they strike the walls of the glass tube, or suitable bodies placed in the tube, they produce a faint fluorescent light. Crookes showed that these cathode rays were capable of being deflected from their original rectilinear paths by the action of a magnet. They thus behave in conformity with the view that they consist of streams of negatively charged molecules, the deflecting action being merely a particular kind of electro-magnetic action, well seen in the deflection of a voltaic arc by a magnet, or in the electro-magnetic motion of the armature of the elec. tric motor.

Hertz discovered that the cathode rays readily pass through thin films or screens of mica, or even of metal. He showed that, in fact, metallic films were even more transparent to the cathode rays than films of mica. For example, when such metallic screens were interposed in the vacuum tube between the cathode and the glass walls on the tube opposite the cathode, fluorescence was still developed in portions of the tube which would have corresponded to the shadow of the screen, had it been opaque.

Lenard, at one time an assistant of Hertz, took the matter up, and showed that fluorescence could be produced by the cathode rays outside the glass vacuum tube. For this purpose, he placed a small window of aluminum in the walls of his vacuum tube, so that the stream of cathode rays would impinge upon this window. A change of some sort appeared to occur at the window. While in the tube, the rays proceeded along straight lines, unless deflected by a magnet; outside the window they preserved rectilinear paths, but radiated in all directions from the window as a source.

These rays, produced outside the vacuum tube by the cathode rays within the vacuum tube, may be called the Lenard rays.

In common with the cathode rays, the Lenard rays possess the power of producing fluorescence in fluorescent substances upon which they impinge. They differ from the cathode rays in the fact that, in the air, they are visible to the eye as a faintly glowing stream or pencil, which rapidly diminishes in intensity, at comparatively short distances from the window. All the effects of the Lenard rays became lost at a distance of a few centimeters from the window, so rapid is their absorption in the air or other media. Hydrogen was found to be the least absorptive, that is, the most transparent medium; but hydrogen, under great pressure, becomes more opaque. Lenard showed that many of the metals are partially transparent to his rays, and that sensitive photographic plates, or films, are quickly blackened by their influence. In fact, Lenard took shadow photographs of opaque or semi-opaque bodies, by interposing them in the path of the rays before they impinged upon the sensitive photographic plate held in a light-tight box, provided with an aluminum cover or slide. Lenard found that the opacity of different substances to his rays varied, approximately, with their density.

In the paper before referred to, Röntgen announced that, when a suitably exhausted vacuum tube is placed under a cover of blackened pasteboard, fluorescent effects can be obtained, not merely at a distance of a few centimeters, but even at a distance of 2 meters, in air. He employed for this purpose a paper screen painted with a solution of barium-platino-cyanide. The Röntgen rays, unlike the Lenard rays, are invisible to the eye, even close to the vacuum tube. No window is necessary in the vacuum tube to produce the Röntgen effect, although Röntgen has produced the effect through an aluminum window. As in the case of the Lenard rays, the Röntgen rays are radiated in rectilinear paths in all directions from the portions of the walls of the tube subjected to the bombardment of the cathode rays.

It will thus be seen that a similarity exists between the Lenard and the Röntgen rays, so far as their method of production is concerned. In each, the source of the rays is to be traced to the impact of the cathode rays upon the walls of the vacuum tube in which they are produced. In each, the rays possess the power of exciting fluorescence in suitable bodies on which they impinge; in each, they possess the power of passing through substances opaque to ordinary light, the opacity in each case increasing apparently with the density, although not in direct proportion.

The Röntgen rays appear to differ from the Lenard rays in the fact that they are not so readily absorbed by air or other media. If no absorption existed, the intensity of the rays would, of course, diminish as the square of the distance from their source. Röntgen claims that he has observed that this rate of diminution in the intensity of his rays does exist within the limits of observational error. This peculiarity of the Röntgen rays has greatly enhanced their practical value.

It will be seen, therefore, that the difference between the Lenard and the Röntgen rays is not marked. The difference appears to be one of degree rather than of kind. There is, however, at least one difference in the rays under discussion. Lenard found that his rays are not appreciably deflected by a magnet when passing through air, but that deflection does occur when his rays were allowed to traverse a highly exhausted chamber. Röntgen mentions that, up to the present time, he has not been able to produce any deflection of his rays by a magnetic field. This has been confirmed by Dr. Oliver Lodge. Röntgen is also experimenting with the action of an electrostatic field, but we believe he has not, as yet, announced any result.

The curious fact pointed out by Röntgen, in the paper before referred to, of the ability of his rays to produce, upon a sensitive photographic plate, photographs of the shadows of, say, the bones of the hand, in the living subject, has naturally caused great popular excitement and interest. There can be no doubt that this fact will prove of great value to the surgeon, especially if, as would seem probable, means are perfected for the production of these rays with increased power.

Röntgen states, as a result of observation, that his rays are apparently incapable of reflection, refraction or interference. If refraction does exist, it must be of very limited amount. These facts have led Röntgen to suggest that his rays are not light in the ordinary physical sense of the term; that is, that they do not consist of a transverse vibration propagated in the ether, according to electro-magnetic laws, but that possibly they may be a longitudinal motion propagated in the ether, a condition which Prof. S. P. Thompson has happily named "ultra-violet sound," and which others have called "ethereal sound" and "longitudinal light."

The details of the method for producing Röntgen rays do not appear yet to have been published by Prof. Röntgen. Physicists, however, have very generally reproduced them, although thus far the shadowgraphs obtained in this country do not present the sharpness and depth which apparently characterise Prof. Röntgen's shadowgraphs.

The authors have successfully obtained Röntgen rays by the use of a large induction coil excited directly by storage cells through an interrupter, the secondary terminals of the induction coil being led directly to the terminals of the Crookes tube. In this case the cathode is the source of cathode rays in the tube, and the surface of the glass, opposite to the cathode, where fluoresence is produced, is the source of the Röntgen rays. We have found, however, as others have done, that by far the best results are obtained by using a high-frequency discharge through the Crookes tube. This is conveniently done by exciting the primary of the induction coil from a 50-volt alternating-current circuit, such as is employed for supplying incandescent lamps on commercial alternating-current circuits, at, say, 15,000 alternations per minute. The secondary terminals of the induction coil are led to a battery of Leyden jars through the primary coil of a Tesla induction coil immersed in oil. The secondary terminals of the Tesla coil are then connected directly to the Crookes tube. Under these conditions torrents of high-frequency discharges pass between the discharging knobs of the induction coil, which are separated to a distance of, perhaps, 5 millimeters, the frequency being determined by the capacity and inductance of the Leyden jar circuit, including the Tesla primary. These high-frequency discharges induce, in their turn, high-frequency and high-tension discharges in the Crookes tube. In such cases both electrodes of the Crookes tube are alternately cathodes, and the glass wall opposite to each electrode becomes fluorescent, and, therefore, the source of Röntgen rays.

The practical difficulties in connection with the production of the Röntgen rays arise from the fact that the Crookes tubes, as ordinarily constructed, are not designed to stand the molecular bombardment of the cathode rays, when of fairly great power, for any considerable length of time. Since the ordinary Röntgen shadowgraphs require exposures lasting, usually, half an hour, and sometimes several hours, a great liability exists to excessive heating of the tubes and the destruction of their vacua. Indeed, at times, the heat produced by the molecular bombardment of the cathode rays is sufficient to melt the glass walls of the tubes, as the authors, most probably in common with others, have ascertained to their loss.

Since the high-frequency discharges obtained by the use of a Tesla coil are not characterised by such marked heating effects, either at the walls of the tubes or in the electrodes, they are greatly to be preferred for producing shadowgraphs. Independently of this, however, they appear to produce a more powerful image. Possibly the velocity with which the molecules are projected from the cathode, or their number, or both, are increased.

A simple form of Tesla coil may be made by winding a primary of about eighty turns of No. 19 A. W. G. cotton-covered copper wire over a glass tube about $\frac{3}{4}$ inch in diameter, and inserting this inside a slightly larger glass tube, over the surface of which has been wound a secondary of about 400 turns of about No. 31 A. W. G. fine silk-covered copper wire. The coil is then immersed in some high insulating oil, such as rosin oil.

In the shadowgraph of such portions of the human body as, for example, the hand, the bones cast the most marked shadows, and the surrounding tissues produce shadows intermediate in intensity. The density of the shadow which is cast upon the plate depends apparently upon the total quantity of matter which the rays have to traverse. Thus, a short passage through a dense substance produces the same depth of shadow as a long passage through a rare medium. In order to obtain sharp definition, the use of a diaphragm is recommended. An iron or lead plate provided with a suitable aperture, and placed between the tube and the photographic plate, is suitable for the purpose.

A photographic copy of a shadow photograph obtained by Röntgen, of a human hand, is here presented on the screen. It will be observed that the shadows cast by the bones are much darker than those cast by the cartilages, sinews, muscles, veins, arteries or integuments.

It is stated by Prof. Silvanus P. Thompson that distinct shadow photographic effects have been produced by the ordinary arc light, so that it would appear that some Röntgen effect is produced by the voltaic arc.

It has recently been discovered by Prof. Pupin and others that, in order to obtain the cathode rays in a vacuum tube, it is not necessary to employ electrodes within the tube itself; but if pieces of tinfoil are placed outside the vacuum tube, and the terminals of the high tension coil are connected therewith, discharges are produced in the vacuum tube by electrostatic induction. These discharges produce fluorescence in the tube, and the fluorescent glass is again the region of Röntgen rays.

This would appear to show that the Röntgen rays are produced by molecular bombardment by the molecules of the residual atmosphere of the high vacuum, and that the metallic cathode is only to be regarded as an auxiliary means for producing this bombardment.

Prof. J. J. Thomson has recently made the extremely important discovery that the Röntgen rays tend to discharge an electrified body on which they impinge, and this whether the charge of the body be positive or negative. Prof. Thomson finds that a charged body constitutes a more sensitive test for the presence of the Röntgen rays than is afforded by either a sensitive photographic plate or a fluorescent screen. This effect takes place whether the charged body be covered by a layer of paraffine, sulphur or vulcanite. In other words, as Professor Thomson points out, *the remarkable fact exists that an insulating layer becomes electrically leaky while being traversed by the Röntgen rays.*

Hitherto no means have been known, beyond mere thermal influence, for altering the electrical insulating power of solid materials by radiant energy of any character. The discovery of this property of effecting electric discharge makes the ray far more wonderful and important to physicists than its property of penetrating opaque solids as displayed in shadowgraphs.

The degree of exhaustion in the vacuum tube, which is the source of the Röntgen rays, appears to be that required for rectilinear molecular bombardment. Edison has shown, experimentally, that below a certain exhaustion the Röntgen effect is negligibly small, while above a certain exhaustion the intensity of the effect again decreases. In general, it may be said that a vacuum which produces a bluish violet light on the passage of the discharge is too low to produce the Röntgen effect. The best results are obtained when little or no discharge is visible within the tube, but the walls are rendered fluorescent with a peculiar greenish tinge. This is usually obtained at about one-millionth of an atmosphere.

Since the Röntgen effect is evidently due to molecular bombardment, and varies with the degree of the vacuum, it would appear that good experimental work can be conducted, both by ascertaining the best degree of vacuum in tubes containing rarefied air, and by ascertaining whether gases other than air will produce, in such tubes, better results.

It would appear that the Röntgen rays must be either a material propagation or an ethereal propagation.

A material propagation would require either that ordinary matter be projected rectilinearly as a whole along the rays, or that some disturbance in matter is projected along them.

The burden of probability seems to be against the assumption that the Röntgen rays consist of a material propagation, since they not only traverse opaque, dense substances, but also appear to be unaffected by a magnet. Assuming, therefore, that the Röntgen rays are an ethereal propagation, they must either consist of a translatory movement of the ether, or of some disturbance propagated along it. Such a disturbance would, probably, have to be periodic or vibratory. The vibrations might be transverse, or they might be longitudinal to the path of the ray. Physical science is acquainted with transverse ethereal vibrations, such being, in fact, electro-magnetic vibrations, or ordinary light. These vibrations differ in their frequency, and, hence, in their wave lengths, but are not known to differ in their speed through free ether. In the ether within material substances their velocity of propagation is reduced, as is evidenced by their refrangibility. This is true of all known transverse vibrations from the lowest frequency, far below the red, produced by the discharge of a Leyden jar and detected only by electrical methods; through the higher-frequency waves, still in the infra-red and constituting direct heat; throughout the limits of the visible spectrum, and beyond the violet in that frequency which is detectable only by chemical or by electric eyes. The marked characteristics of these transverse vibrations are their refrangibility, their reflectibility and their possibility of interference; characteristics which are all apparently wanting in the Röntgen rays.

It would, therefore, appear that the Röntgen rays are not transverse vibrations of the ether. If they are, they do not appear to lie within the range of frequency hitherto explored, a range extending from about 100,000 to about 1,000,000,000,000,000 (a quadrillion) waves per second. There is reason to believe that if they have a wave length, this wave length is long compared with that of visible light, since they pass through appreciable distances of gross matter, distances measured in centimeters or hundredths of a meter, rather than in microns or millionths of a meter. Such waves would correspond to dark heat waves, in the infra-red.

It is known that ultra-violet light possesses the power of discharging a negatively charged body upon which it falls directly, while, as Prof. J. J. Thomson has discovered, the Röntgen rays can discharge bodies either positively or negatively charged, even while imbedded in a layer of highly insulating material.

Dr. Lodge has shown that when polarised ultra-violet light strikes such a negatively charged polished plate, it is most effective in producing discharge when striking at an angle, instead of perpendicularly, and, consequently, the discharge may, perhaps, be effected by a longitudinal component of the impact. This seems to favor the supposition that the Röntgen rays are longitudinal ethereal vibrations.

The material substances with which we are familiar, and which are capable of transmitting vibrations transversely to the direction of propagation, are also capable of transmitting longitudinal vibrations. The fact that longitudinal vibrations in the ether have hitherto remained undiscovered has caused no little inconvenience in the framing of hypotheses concerning the action and properties of the ether. If ether resembles material substances, its velocity of propagation for longitudinal vibrations would be much greater than that of its velocity of propagation for transverse vibrations; consequently, for any given frequency of vibration, the wave length would be greater than that of light waves.

Summing up, then, while it is far too early to form a reliable conclusion concerning the nature of the Röntgen rays, such evidence as does exist would appear to favor the theory of longitudinal vibrations in the ether.

Whatever may be the future of the Röntgen rays, so far as their practicable applicability or scientific value is concerned, great praise must be accorded to Professor Röntgen for the exceedingly interesting and important contribution he has made to this branch of molecular physics.

LABORATORY OF HOUSTON & KENNELLY,
FEBRUARY 16, 1896.

DISCUSSION.

DR. A. E. KENNELLY.—Having contributed to the paper of this evening, I have very little to add to what has already been stated in it; but a few remarks upon the possible future of the Röntgen rays may be admissible at the present time.

The future may be regarded from a practical and also from a theoretical point of view. There can be no doubt that the Röntgen rays, which render indirectly visible to the eye the bones and interior tissues of the body, must be of great value to the surgeon, anatomist and biologist. It only remains to strengthen and develop these rays in order to extend their range of application. The rays lie, at present, under the troublesome disability of absence from bending or focussing by reflection or refraction. It may be that indirect means may be employed to overcome this difficulty.

From a theoretical point of view the subject is full of interest. Its investigation cannot fail to increase our knowledge of molecular physics and the physics of the ether. Should the rays prove to be of a nature hitherto unrecognised and unknown, an entirely new channel of communication with the unknown world is opened up. I cannot but believe that the great interest which has been bestowed upon this fascinating subject all over the civilised world indicates more than a mere passing fancy or tribute to the most recent scientific passion, that it points to a general effort on the part of the entire civilised community to become acquainted with the new manifestation of Nature, which has, for years, been clamoring at the doors of our senses for recognition, and that it indicates a consciousness that we have before us a most potent agent to aid us in wresting from Nature her secrets in the invisible domain. We all know that advances in sciences are made in epochs, or wave-like periods of activity. May we not hope that this wave of public interest is one whose crests shall lead us to fortune?

I think it would be most fitting that a vote of thanks should be offered to the scientific worker in Bavaria, whose labors have been so fortunately crowned with success, and I beg to propose that such a vote of thanks be extended to Professor Röntgen, by this meeting, for the interesting and important work which we are discussing this evening.

[This motion was numerously seconded, and, on being put to vote, was adopted unanimously.—THE SECRETARY.]

PROF. ELIHU THOMSON.*—From my experiments it appears that the cathode rays are produced only when the vacuum in the Crookes tube is such that little or no light, other than that arising from fluorescence of the glass, is given out. A degree of exhaustion somewhat higher than this stops the electric discharge, while a somewhat lower vacuum, although giving abundant fluorescent light on the glass walls, gives, also, an illumination of the residual gas in the interior, and no cathode rays.

While using one of my tubes, it was noticed that, during the passage of the discharge, the vacuum continually improved, and soon became so high as not to permit the discharge to pass at all. This was doubtless due to the fact that one electrode was of platinum instead of aluminum, and that the platinum was carried from it to the sides of the tube and deposited there as a smoky layer. This finely divided metal absorbed the residual gas and so far completed the exhaustion as to prevent the passage of the discharges, even when of very high potential. In this connection it may be mentioned that the vacuum in an ordinary incandescent lamp commonly improved during the use of the lamp. I have found old, discarded lamps, with worn-out or broken filaments, to have excellent Crookes vacua, and sometimes vacua through which no discharge would pass, while new lamps are rarely to be found with so high exhaustion. The reason of the change in the vacuum in this case is doubtless the absorption of residual gas by the film of carbon or soot deposited gradually on the interior of the bulb in the old lamp.

---

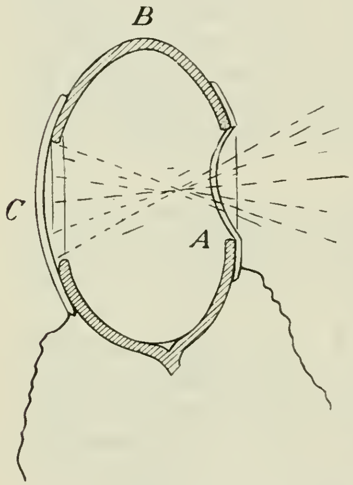
* Correspondence.

These old lamps may, in fact, when provided with thin aluminum caps outside the glass bulb, give rise to cathode rays when excited inductively by an apparatus giving alternating currents of high frequency.

It appears to me probable that a Crookes tube, provided with a side tube containing potassium hydrate, and exhausted to the highest possible vacuum, will present advantages as a generator of Röntgen rays; for, by warming the hydrate, the degree of vacuum may be controlled or adjusted to that proper for obtaining the best effects.

In order to render it possible to use a large amount of energy in excitation, to the end that the vigor of cathode rays emanating from the apparatus may be made a maximum, it may be possible to construct tubes like the accompanying sketch, where *B* is the vacuum bulb having two openings or windows opposite each other. One of these, as *C*, is capped with a cup of sheet aluminum, cemented on, and having a surface concave to the vacuous interior. The other opening, *A*, would be capped by a very thin cover of aluminum, made, for strength, convex to the interior space. Cap *C* would be made the cathode and *A* the anode. The rays would converge near *A* within the bulb, then diverge through *A* in passing out into the air. If the whole bulb, except the window *A*, be immersed in oil in a surrounding box, the outside insulation, as well as the cooling of the tube under vigorous excitation, is provided for.

The current best adapted for the development of cathode rays would naturally be a continuous current of from 50,000 to 100,000 volts. Its strength would be made as great as the tube or bulb itself could bear without injury. It is difficult, however, to obtain such currents, while it is very easy to obtain, with simple, cheap apparatus, high-frequency, high-potential alternating currents, which, while not so effective as continuous currents, may be had of any power.



Cathode rays may be detected, as is well known, either by the photographic plate, or by their power of exciting fluorescence. It is conceivable that a simple instrument, such as a blackened tube, having a screen with fluorescent material near one of its open ends, and a sight-hole at the other, might, for practical purposes, be superior to the photographic plate, inasmuch as the exploration desired would be accomplished in a short time and with changing directions of transmission of rays. In this case, of course, no permanent record would be made.

A third method of detection of cathode rays is based on their power to cause discharge of electrified surfaces. An electrified body, connected with an electroscope for indicating its charge, if exposed to the cathode rays, is at once discharged. Recent experiments made at the Massachusetts Institute of Technology have, it is reported, shown that this electrical test will instantaneously detect the rays that have passed through a thick brass plate (about ½ inch) and very heavy plates of vulcanite.

There can be little doubt that means will soon be found for greatly accelerating the making of shadow pictures by cathode rays. Were it possible to produce plates sensitive only to the rays absent in sunlight or ordinary artificial light, it would follow that the taking of the impression could be carried on in a light room with an uncovered plate, and the development of the same carried on without a dark room.

There is yet, of course, much to be learned concerning the real nature of the rays and their relations to ordinary light and heat rays. I incline to the opinion that it is not necessary to consider the cathode rays as differing in kind of ether vibration from light waves, until it is proven that electro-magnetic waves of very high pitch must, of necessity, undergo reflection and refraction at surfaces.

The characteristics of cathode rays appear to be the same in many respects as those of ultra-violet light; both effect chemical decompositions, both cause fluorescence and phosphorescence, and both provoke discharge of negatively-electrified bodies.

May not cathode rays, therefore, be ordinary transverse electro-magnetic waves in the ether, as are light waves, but of such high pitch, relatively thereto, as to be beyond the vibration period of atoms in the molecules of ordinary matter; and that, as a consequence of such high pitch, they can neither be reflected nor refracted, but can travel through bodies in the assumed free ether between the molecules?

It might easily be that, when obstructed by the molecules, absorption takes place from internal refraction or reflection, and absorption would then depend on the amount of matter traversed, as measured by its density and thickness.

It is true that the crude view thus presented may involve changes in our ideas concerning the true causes of ordinary reflection, refraction and dispersion of light. At all events, the new discovery will, in my opinion, become a mighty weapon for attacking anew the problem of the relations between what is called gross matter and the universal ether. We may be able to make one further step towards unifying the Universe, as when it be shown that in all probability the chemical elements, as we know them, are but modifications in the ether, in somewhat the same way that polymeric bodies depend, in structure, upon modifications of much simpler atomic groupings.

PROF. A. E. DOLBEAR.*—It is remarkable what an amount of photographic activity has been induced by Prof. Röntgen's announcement. The physical laboratories of the world appear to have well-nigh dropped everything else in order to duplicate that work and ring the changes on it, and the experimenters are daily besieged by the multitude of reporters from the daily press, anxious to be the first to describe whatever is done. The utility of it is what gives it its chief interest to the public, as it very properly should, for there is now no foreseeing what great importance it may presently have. To the scientific man, as such, the interpretation of the phenomenon is of first importance, and here the question very properly arises: Is this discovery so radically new as it appears, and is there any reason for assuming the existence and activity of rays or ether waves of a different kind from any heretofore known?

As to the first, it has certainly been known by myself for nearly four years that photographic action would take place in the dark through the activity of waves set up by electric discharges in the air. In 1892, I made a profile of a five-pointed iron star on a photographic surface when the latter was separated from the sparks by the top of a table an inch in thickness, and ordinary light in other ways was excluded. I had expected it from thinking upon the theory of photographic action and of ether waves. I did not publish anything about it at the time, because I came across, somewhere, a scrap saying that the same thing had before been accomplished by another, I do not remember by whom or when. However, I published, in April, 1894, an article in the *Cosmopolitan Magazine*, a copy of which I attach with this,† which will show that the knowledge of the fact and the explanation, such as it was, was already in my possession. *Cosmopolitan Magazine* articles have to be prepared two or three months before the date of publication, and that article was written more than two years ago.

---

* Correspondence.

† "For a long time it was believed there were three different kinds of ether waves, known as heat, light and actinic rays. The latter were supposed to be the ones that produced the chemical action on photographic plates, while

There was nothing said about X rays, or cathode rays, for the very good reason that, so far as my experiments

---

light consisted of rays of a different kind, capable of affecting the eye. It was discovered, however, that the same rays which can produce vision can also heat a body, and also do photographic work; and what any ray can do depends upon the kind of matter it falls upon, so that all rays have similar characteristic properties. This discovery makes it plain that there is no peculiar kind of ether waves which can be called light, as distinguished from other kinds of ether waves. What is called light is a physiological phenomenon, and has no existence apart from eyes. So well assured is this, that the serious proposal is made to banish the word 'light' from physics.

"The sensitive coating upon a photographic plate is an unstable chemical compound, which may be broken up by mechanical pressure, by heat, or by ether waves. The proper wave length for a given plate depends upon the nature of its surface. The tanning of the skin, the darkening of newly laid shingles, the coloring upon apples and other fruit, is a photographic process, as can be shown by shielding them from the sun's rays.

"It has long been known by photographers that pictures may be taken with ether waves much too long to be seen by the eye, if some other substances are used in place of the simple silver salts in common use.

"Since it has been shown that ether waves of all lengths have an electromagnetic origin, it has been apparent that all the effects of light can be duplicated with suitable electric apparatus. Lay a coin like a half-dollar on a plate of glass, and let a few sparks from an electric machine fall on it. Remove the coin and the glass surface will not appear to have been affected; but if it be breathed on, the image of the coin will at once be seen, and that it is really engraved on the glass surface is evident, for it will not easily rub off. If a piece of photographic paper takes the place of the glass, it will have the imprint of the coin made upon it. It is not needful to have the sparks fall upon the coin, for, if it be enclosed in a dark box brought near to an electric machine having short sparks passing between its knobs, the ether waves set up by the latter will be sufficiently short to affect the photographic surface, which may be developed afterwards in the ordinary way.

"So it is actually possible to take a photograph of an object in absolute darkness with the ether waves set up by working an electric machine. Not much has yet been done in this direction, but it is a new clew to chemical possibilities, and one may confidently look forward to the time when the qualities and colors of surfaces of many things will be changed to suit the taste by an application of electric waves of suitable length to bring about the proper chemical reactions, and an electric machine may become a necessary adjunct to the apparatus of the photographer."—*Cosmopolitan Magazine, April, 1894* went, only ordinary means and apparatus had been employed, and there had been found no necessity for assuming that the work done necessitated other kinds of waves than such as I supposed myself to employ. Dr. W. J. Morton, of New York, and others, have lately reported similar experiments, which corroborate the proposition that vacuum tubes, as such, have little to do with the phenomenon.

As to what was generally known about the fundamental principles, it may be said that it was not new to photograph by waves either too short or too long to be visible. Photography can go on wherever fluorescence is possible, and ultra-violet waves have long been known to be effective for that purpose. Dr. Draper, fifty or more years ago, got photographic effects in the region beyond the red; and Captain Abney, in England, long ago photographed the whole spectrum a long way above and below the visible part. Hence, photographing with invisible rays, either long or short, is not new.

After Hertz's work was published everyone has known that ether waves set up by electric action were initiated in the discharges of Leyden jars and condensers in general, and that the wave length depended on their capacity; also, that such discharges always set up phosphorescent and fluorescent action in gases and solids; that is, relatively long waves were capable of producing phosphorescence.

That such waves, invisible to the eye, were capable of passing easily through bodies opaque to visible or certain definite wave lengths, has been known for many years. Iodine in bisulphide of carbon is opaque to the eye, but very transparent to other waves, and Tyndall raised bodies to incandescence by such passed through that medium. He called the phenomenon *calorescence*. Afterwards, Bell showed that vulcanite was similarly transparent, while Hertz proved that stones, wood, etc., were transparent to waves set up by electric discharges.

All this shows that the data for supposing that such shadow photography as we now have, even to the distinctions between bone, muscle and bullet, were common knowledge.

What Röntgen did was to take a picture of his hand, showing the bones. If he had taken a picture in a similar way of a coin only, the interest in the experiment would have been small until some one had done *that particular thing.* It is that which has pushed the matter to its prominence, and rightfully so, for it has given photography a new field, which, though lying close at hand before, had not been entered on the physiological side, and which promises practical applications of great value.

As to the interpretation that may properly be given, or attempted, it may be too early to do more than believe very gently. It is evident that a phenomenon involving phosphorescence, fluorescence, photography, transparency and opacity, long and short waves, their origins and properties, is tolerably complicated; but for myself, I should say that every effort should be made to find the explanation with the transverse waves we know, and take the longitudinal wave only as the last resort. When one reflects upon the well-known phenomenon, fluorescence, that it is not only the transforming of short waves to longer ones, as in eosin, but also the transforming of long waves into shorter ones, as happens with chlorophane, which changes waves much longer than the red rays into emerald-green waves. Hence, it is entirely within proper bounds to expect that rays made too long to be appreciably refracted can act upon a phosphorescent body so as to produce waves capable of doing photographic work.

Again, there does not appear to be any good reason for thinking that an electric discharge can produce among atoms and molecules particular movements and resulting waves different in kind from other agencies, say heat, for instance; and if so, the same rays found in electric discharges in the air, and from Crookes tubes, are to be found in other sources of light as well, differing perhaps in degree, but not otherwise.

DR. JOSEPH W. RICHARDS.*—Since the shadow pictures are made through substances ordinarily considered opaque, it has been assumed that the *light* rays have nothing to do with casting the shadow. It should be remembered, however, that substances are only *relatively* opaque. Strong sunlight shows the bloodvessels in the ear, even the veins in the hand. Even metals are translucent if in thin enough films. Magnetic iron oxide, the most opaque of all substances, is translucent when crystallising between leaves of mica. There is no substance known to science which is absolutely opaque, even to ordinary light rays.

---

*Correspondence.

We know that heat rays can pass through substances opaque to ordinary light. Can we not readily imagine a *thermo*-graph, made on a plate very sensitive to heat rays, placed behind a screen cutting off ordinary light? Substances would cast shadows on such a plate in proportion to their transparency or opacity to radiant heat.

Coming now to the X rays, I believe they act on an analogous principle. It is said that they are difficult of refraction. If this is so, may it not be because they are so far below the ultra-red rays that their index is so small as to have escaped observation? The very long waves of Dr. Hertz passed through wood, etc., like the X rays, but he refracted them by a huge prism of pitch. There seems to me to be many points of resemblance between Dr. Hertz's rays and these X rays.

Metals have the highest known indices of refraction for light rays. Allow me to suggest that *metallic* lenses (as of aluminum) may enable the X rays to be refracted and focussed.

Glass is said to intercept or weaken the X rays. Possibly the glass bulb of the Crookes tube, therefore, weakens the effect. If the bulb were made of celluloid, or some other available material transparent to the rays, heightened effects could be obtained.

A rigid search will probably result in the discovery of films more sensitive to these X rays than even our most instantaneous light plates. It is not only possible, but even probable, that there exist such compounds, the use of which would give us *quick* plates for the X rays.

There is no reason why the X rays cannot be generated on a much greater scale than heretofore, and thus more striking results be obtained. Experiments with other metals than aluminum in the discs may result in showing that the effects are modified by the kind of electrode emitting the rays.

PROF. GEO. A. HOADLEY.—Having seen several statements in the newspapers quite recently that Röntgen photographs could be obtained in the electrostatic field of a Holtz machine, I have thought it might be of interest to show that the effects thus produced are not due to the Röntgen rays.

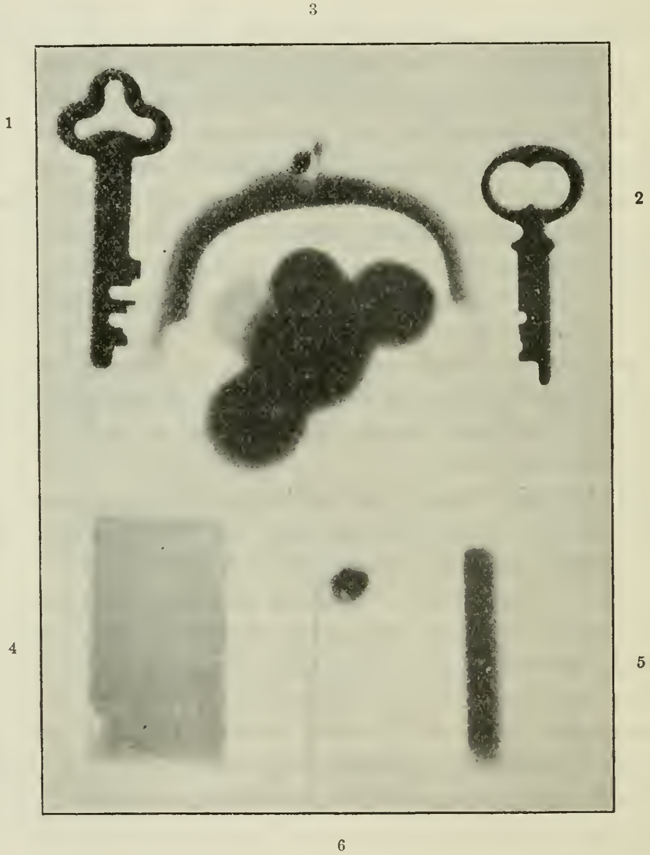
The first two lantern slides, which I show you, were made from negatives obtained by placing a coin upon a photographic plate, wrapping the two in several thicknesses of black paper, and placing them between the knobs of the machine, when they are at the proper distance to produce the brush discharge.

At all points where the coin was in contact with the plate, the effect of the discharge is seen showing the lettering, figures and date, while around the edge is a rim of minute radiating lines.

The third slide shows the effect of the condenser spark on both sides of the plate, the one on the rear side being much less distinct than the one on the film.

MR. W. N. JENNINGS.—I had the honor of showing, in this hall, six years ago, the image of a silver dollar, made in precisely the same way as those now shown; also a spark taken on the plate direct. These photographs I also used in connection with my lecture before the Institute last April, and explained fully, at the time, how the pictures were produced. I make this statement now for Professor Hoadley's information, and merely to place the matter on record.

MR. JOHN CARBUTT.—Naturally, the announcement of Professor Röntgen's discovery of photographing the invisible, with what he terms X rays, attracted my attention, the more so as I saw that a new field had been opened for the use of dry plates. The length of exposure required particularly interested me, and I therefore commenced experiments to produce, if possible, a plate that should be more sensitive to these X rays than the ordinary rapid plate. The tests made on these new plates which I have prepared have enabled me to reduce the exposure from one hour to twenty minutes, when making a shadowgraph of the human hand. Professor Goodspeed, of the University of Pennsylvania, kindly placed at my disposal the Crookes tube and coil with which he had made his experiments. Placed on the box holding the X ray dry plate was a purse containing a number of coins, including a disc of aluminum;



Copy of picture made with one of Carbutt's Special "Röntgen Ray" Plates (exposure, 21 minutes). 1–2, flat steel keys $\frac{1}{16}$ inck thick; 3, leather purse with steel clasp, containing coins and disk of aluminum; 4, sheet of glass; 5, aluminum rod $\frac{1}{4}$ inch thick; 6, imitation diamond pin.

alongside of the purse were two flat steel keys; below these a piece of ordinary window glass; in the center, beside this, an imitation diamond pin; and, on the lower right-hand corner, a piece of rod aluminum. Two exposures were made, one of twenty-one minutes and the other thirty minutes; the negatives were at once developed, using my "J. C. Tabloid Developer." The plates developed up in the normal time usual to a fully exposed plate, and the results were pronounced by Professors Goodspeed and Richardson superior to any they had obtained, even with a much longer exposure. The transparency now on the screen shows that the X rays obliterated the leather of the purse and passed through the aluminum disc and the piece of glass in about the same ratio.

PROF. CHAS. F. HIMES.—I made some experiments with Crookes tubes and a coil giving 7-inch sparks, but with negative results, which I attributed to the absence of the peculiar rays from the light I employed. Thereupon, I turned to sunlight as possibly containing some similar form of energy transmissible through substances opaque to visible light, and made the following experiment: A thick piece of ebonite was placed in an ordinary photographic plate-holder, and upon it a Carbutt "Eclipse" plate, separated from the ebonite by strips of heavy cardboard. Several pieces of black paper were placed upon the plate, and then the felt-covered hinged back was fastened in. The ebonite was then exposed to bright sunlight, partially covered with a ring of sheet brass having a central circular aperture of about $\frac{3}{4}$ inch. After an exposure of twenty minutes, prolonged development gave no apparent result. An extreme exposure of three hours and a half was then made at midday in bright sunshine, and less prolonged development gave the unexpected result of a dark ring on a light ground with a light center, or a positive. Regarding this as a reversal by over-exposure, another exposure of forty-five minutes was made, which, upon development, gave a negative or light ring on dark ground with dark center.

I do not say that Röntgen rays are involved, but this experiment proves at least this much—that there is a form of energy in the sunlight, transmissible through ebonite, and, perhaps, through other opaque substances, and which, perhaps, is also present in other sources of light. I have not been able, however, to detect them in magnesium light. As the plates were separated from each other by the thickness of the cardboards, and the temperature at the time was near 0° F., the result seemed only explicable by the transmission of the rays by the vulcanite. A similar exposure to rays from a warm iron plate gave no developable effect, although the vulcanite became sensibly warm.

It will be *apropos* here to recall the oft-cited experiment of Abney, of photographing with the rays from a tea-kettle as having some interest in connection with the subject of this evening's paper.

The photographs so-called were simply shadowgraphs. A card with perforations was held above the sensitive plate, and a hot tea-kettle placed above the card, and, after a short exposure, the plate, upon development, showed spots of the shape of the perforations. But a much more remarkable experiment, made by this investigator at the same time, more than ten years ago, was the photographing of the carbon points of an arc light through a piece of vulcanite with an ordinary lens, in about thirty seconds.

I regard as the most suggestive feature in connection with these experiments, that Abney was illustrating and emphasising the possibility of imparting peculiar kinds of sensitiveness to bromide of silver by suitable treatment, and thus of obtaining photographs by ultra rays, and that he was calling attention to the particular modification he had produced. The transmissibility of rays through vulcanite was an incident. It seems to me that much of the progress of the new photography must lie in the direction of the production of films peculiarly sensitive to these so-called X rays. All recent progress in photography has been in the direction of the preparation of films responsive to any peculiar demand, and it is a matter of great gratification to learn that Mr. Carbutt has already recognised this new field for his activity, and that there is every reason to hope, from his known success in meeting all demands hitherto made upon him, and his character as an indefatigable experimenter, that he will be able soon to furnish us X ray plates that will permit the use of sources of light more readily available.

Referring to my own unsuccessful experiments with the Crookes tube, I should state that such a result ought to have been anticipated. The tube employed was the so-called shadow tube of the set, and was an excellent one for the purpose for which it was designed, but the cross of aluminum, which produced a shadow on the fluorescent ground of the tube, almost constituted a test for effective rays and indicated the almost complete absence of any that would pass through aluminum under the conditions present in the tube. Other shadow tubes giving less perfect shadows might furnish more of the active rays.

MR. JAMES WILSON.—The paper just read has described very thoroughly the effects and peculiarities of the Röntgen or X rays. A description of the Crookes tube, in which these rays are generated, might aid a little in the discussion of the mystery.

In 1884, when the Franklin Institute held its great Electrical Exhibition, Mr. Chas. H. Richardson and myself had the care of the exhibit of electrical and scientific instruments of Queen & Co. In that space we had a dark room to show Geissler and Crookes vacuum tubes. This experience and years of handling and testing Crookes tubes, when received and sold, enabled us to become more or less familiar with Professor Crookes' theories of "Radiant Matter," or, as he termed it "The Fourth State of Matter."

I, therefore, venture to offer a theory that will partially explain the cause and some of the peculiarities of the mysterious X rays, that have been so ably treated in the paper just presented by Drs. Houston and Kennelly. In December, 1878, Dr. Wm. Crookes described before the Royal Society of Great Britain his various experiments, to prove that there is a state of matter beyond the gaseous, in which the molecules of matter, having so much more space to move freely, have their mutual attractions altered, thereby giving the same chemical material new physical properties, making it as much different from a gas as a gas differs from a liquid, or a liquid from a solid. For example, two atoms of hydrogen and one atom of oxygen combined chemically form one molecule of water. These water molecules may be arranged together in the form of solid ice, liquid water, or gaseous steam, the difference being one of pressure, or temperature, or both.

In a gas the molecules can move freely among themselves, having lost much of their mutual attraction or cohesion.

At the ordinary pressure of the atmosphere, 15 pounds per square inch, if a vibration or motion is imparted to a molecule of a gas, it can move only an exceedingly small distance without striking another molecule. Dr. Crookes found that, when the pressure was removed, each molecule could then move a considerable distance without striking another; and that, under the influence of an electrical discharge or vibration, they acted differently from when in the gaseous state.

When a glass tube, having metal electrodes sealed through the glass, is partly exhausted, and placed near a Holtz glass-plate electrical machine, or in the secondary or tertiary circuit of an induction coil in operation (potential of 20,000 to 50,000 volts), there is a stream of light, usually violet, from one electrode to the other. At about $\frac{1}{1000}$ of an atmosphere exhaustion, the stream of light seems broken into numerous stratifications of light and darkness, and although the negative end of the tube is always brightest, there is a space close to the metal of the negative electrode where there is no light. Dr. Crookes explained the dark spaces between the stratifications and around the negative pole as the "*mean free path of the molecules;*" *i. e.*, the average distance that a molecule could move without a collision with another molecule.

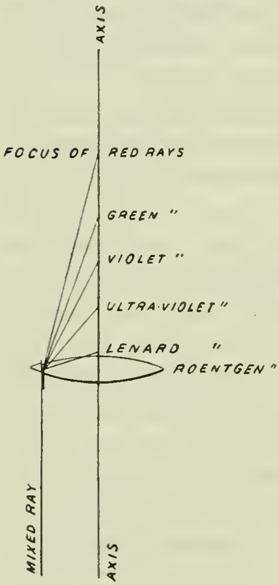
At low exhaustions, no matter how the tube be bent, the discharge or stream of light goes from one electrode to the other, and if the tube be brought near a magnet, the stream of light is attracted or repelled, as though it were a conductor carrying a current of electricity. If the exhaustion be increased, the dark space about the negative electrode grows larger, until it fills the entire tube. At an exhaustion of about the $\frac{1}{1000000}$ of an atmosphere, there is no stream of light from one electrode to the other. The stream of light meant collision of molecules ; now the molecules can move the entire length of the tube without collision ; where they strike the glass, they set the *molecules* of the glass into vibration, producing a fluorescent light, the color depending on the composition of the glass. The molecules move in straight lines from the surface of the negative electrode (cathode), no matter where the positive pole be placed. If the glass tube be curved or bent, the flying molecules will not turn the corner. If the negative electrode, or cathode, be in the form of a flat plate, the molecules will fly from it in parallel lines; if it be concave, like a saucer, they will fly from it to a focus; if there be two cathodes, the streams of molecules from each repel each other. Dr. Crookes' explanation is, that as the molecules floating in space come in contact with the electrically-charged plate (cathode), each one becomes similarly charged and is repelled, and, there being no resistance to their motion, they fly with great velocity. A few are deflected by collision with other molecules coming slowly toward the plate. Others strike the glass without collision with other molecules, thus producing the greatest effect on the glass at one spot directly opposite the negative electrode. If any substance be placed in the path of the molecules between the negative electrode and the glass, a shadow of the substance will appear on the glass. If the substance be capable of fluorescence, it will glow with a characteristic color, when placed in the path of the molecules—a diamond glowing with a light equal to that of a candle. If the cathode be made concave, and a piece of platinum foil be placed at the focal point, it will be heated white-hot and fused, showing that the energy of the bombarding molecules can be changed into heat. If a magnet be brought near the tube, the focal point can be deflected, and a hole melted in the tube. If a light wheel with vanes be placed in the tube, and the flying molecules allowed to strike against the vanes, the wheel will revolve rapidly. These flying molecules, whose direction depends so much on the form of the negative electrode, have been called *cathode rays*. The X or unknown rays, that are capable of affecting a sensitive photographic plate through substances that are opaque to light, seem to start from the fluorescent surface of the glass, the greatest effect being produced on the photographic plate, when this is placed opposite the part of the glass subject to the greatest bombardment. From the fact that the rays inside the tube can be deflected by a magnet, and the X or unknown rays outside the tube cannot be so deflected, it is assumed that there are no X rays inside the tube, and, of course, there are no cathode rays outside of the tube. X rays seem to differ from all other forms of energy, except in one particular—they act on a photographic plate like light waves.

The question is, what are they? A ray of light is affected by a powerful magnetic field. The paper of the evening explains that the principal difference between Lenard rays and Röntgen or X rays is, that the Lenard rays are affected by a magnetic field, and the Röntgen rays are not. The suggestion that they are longitudinal vibrations in the ether only adds to the mystery, because the existence of the *ether* itself has never been proven, it being itself merely an imaginary X quantity adopted to supply the missing link needed to make the wave theory of light plausible.

Accepting Dr. Crookes' theory of what happens inside the Crookes' tube, I hold with those who think that the Röntgen and Lenard rays are both similar to light rays, and are ultra-violet light, and that they bear the same relation to ordinary light that harmonics or overtones do to a fundamental sound. The accepted theory of fluorescence is, that the fluorescing substance receives waves of a certain rate of vibration, and transforms them into waves of a different rate of vibration, usually changing short, rapid waves, into longer, slower waves, and, in some instances, the reverse. If a beam of light from a slit be passed through a prism, and the spectrum thrown on the wall, we can readily note about where the red begins and the violet ends. If a piece of paper painted with a solution of quinine be placed beyond where the violet ends, what before was darkness now appears light; part of the invisible ultra-violet light has been made visible, because the quinine changed the rate of vibration low enough to bring it into the range of what our eyes are capable of seeing. If we had eyes adjusted to be sensitive to these rapid rates of vibration, we might be able to see the ultra-violet light without the use of quinine, or any fluorescing substance, and even X rays might be visible.

To make a comparison with sound, for the purpose of illustration, go to a piano and hold a key down softly without striking the string, then strike suddenly the octave higher; the first string will be set in vibration by the second, and will give a mixture of the sound of its own fundamental tone, and that of the octave higher and its overtones. This phenomenon might be called fluorescence in sound, the relative effect being the same as fluorescence in light. The left or lower end of the piano keyboard may be compared with the red, and the upper or right end, with the violet, of the spectrum. Beyond the piano keyboard limits, there are tones to which our ears cannot respond in unison; beyond the spectrum there are light vibrations our eyes cannot appreciate. When the different instruments in an orchestra, in tuning, sound in succession the key-note of A, it is easy to distinguish and name the instrument that makes the sound, yet they all sound A. The difference is called, in acoustics, *timbre*, meaning the difference in number and particular overtones sounded by each instrument in addition to the fundamental or key-note.

Most large orchestras have two or three kettle-drums, a membrane screwed over a copper kettle and tuned to give one particular fundamental note only. If we drop pebbles or sand on it, or if we could provide a membrane that would not absorb water and stretch out of tune, we could place it out in a shower of rain and get the musical note and its overtones, the same as if pounded with drumsticks. The action of the Crookes tube and the kettle-drum may be compared. The bombarding molecules of air strike the glass as the globules of rain strike the membrane of the drum; the membrane is tuned to one fundamental note, and has its overtones or harmonics, one, two, three, five, etc., octaves higher, with some fifths and thirds, all mixed, together giving the characteristic sound of a drum. The glass molecules are tuned, so to speak, in the case of the Crookes tube made of ordinary German glass, to the key of G, or green light, and, when set in vibration by the bombarding air molecules, give forth the fundamental green which we see. The overtones or harmonics being some octaves, thirds and fifths above, are Lenard and Röntgen rays of ultra-violet light, Röntgen or X rays being possibly some octaves higher than Lenard rays. The reason that aluminum gives off X rays apparently without fluorescence may be due to the fact that the molecular fundamental light tone of aluminum may be itself beyond the violet; that is, its fluorescence is beyond our eye limit.



If light be a transverse vibration of molecules, there is no reason why wave motion should stop abruptly at violet, or an octave beyond violet light. Mathematically considered, wave motion should continue until it merged into a straight line or infinity. We might assume that when transverse vibrations became exceedingly small they would merge into longitudinal vibrations, which would be represented by a straight line when compared with a wavy line, representing transverse vibrations. The ultra-violet or harmonic theory may also explain why they have not been refracted. (See accompanying sketch.)

The focus of the red rays, passing through a lens or prism, are always refracted farthest from the lens; the violet rays are brought to a focus much nearer the glass; the ultra-violet would be still nearer, and the Lenard and Röntgen rays would possibly not get out of the glass; they would be absorbed. If a very thin lens of long focus were tried with sufficient force of rays to penetrate to the focal distance in air, some Röntgen rays might be found between the violet focus and the lens; or, if a lens were made of a very light material, whose density and composition would have nearly the same relation to X rays that glass or water has to light waves, the X rays might be refracted. Air seems to obstruct the passage of X rays, which means that their energy is absorbed in trying to start the air molecules vibrating at an X ray rate, or some octaves lower; therefore, any substance placed around the Crookes tube, which is capable of vibrating at an X ray rate, or an octave near it, should transmit X rays freely.

If a Crookes tube be made, similar to the form in the communication of Prof. Elihu Thomson, and on the side of it from which the X rays are to emerge another lens-form tube be blown—this extra lens-form chamber to have a Geissler-tube vacuum—it is probable that the rays would be partly refracted, sufficient to concentrate them.

From what we know of the sun as a source of energy—of heat, light and electricity—Röntgen rays are, undoubtedly, shed upon us in great quantity; and as the air obstructs and absorbs some of those given off by the Crookes tube, possibly most of the X rays from the sun are absorbed before they reach the earth. A fluorescing substance may yet be discovered that will harmonise more readily with X-ray vibrations from the sun than anything yet known, reducing their rate of vibration sufficiently near that of violet light, after passing through substances opaque to ordinary light, to permit us to see them. There will then be no need of Crookes tubes. The sun will do the part of the induction coil and cathode, the higher atmosphere will be similar to the interior of the Crookes tube, and the lower atmosphere will act the part of the fluorescing glass. We will try to do the rest.

If it can be proven that X rays are vibrations similar to those of ultra-violet light, but more rapid, the name X rays, instead of being the algebraic sign for the *unknown*, may mean that their proper place in the spectrum is where the Frauenhofer line *X* would be; line *A* being in the extreme red end, D in the yellow, E in the green, H in the violet, I, J, K, and so on to X, beyond the violet.

The assumption that X rays are longitudinal vibrations in the ether may be harmonised with the ultra-violet light theory, by premising that X rays are *caused* by longitudinal vibrations in the ether; for, if this imaginary ether be perfectly homogeneous, filling all space, the vibrations started by the sun may be longitudinal until they reach our atmosphere, where they may be transformed into other forms of vibration, electric, heat, light, and X or Röntgen vibrations.

Of course, statements like these, made in an extemporaneous discussion of such a profound scientific mystery, must be regarded merely as suggestions. Practical investigators will, I believe, soon discover new facts sufficient to establish a theory that can be proven experimentally, and enable mankind to more thoroughly utilise this latent force of Nature.

MR. A. E. OUTERBRIDGE, JR.—Mr. President, I came to this overflowing meeting, only to look, to listen, and to learn something of this strange discovery, respecting the precise nature of which there is at present so much speculation and vagueness of ideas.

I did not expect to be able to contribute any information to this symposium; but while listening to the address of Drs. Houston and Kennelly, my mind reverted to a memorable occasion, nearly eleven years ago (which some of those now present can, no doubt, recall), when the famous physicist, Sir William Thomson, now Lord Kelvin, during the electrical exhibition held under the auspices of the Franklin Institute, gave, at the Academy of Music, a most enlightening lecture upon "the wave theory of light."

This address made a profound impression upon my mind, and gave me a new intellectual comprehension of the scientist's mathematical conception of the nature of light waves, propagated through the luminiferous ether, as distinguished from sound waves, travelling through the air, and also indicated a possible though unknown analogy. I can vividly recall in my mind's eye, at this instant, the moving diagram upon the screen, exhibiting these two distinct forms of wave motion, and although I cannot now repeat the precise words then used by the lecturer, the substance of his remarks was, as I recall them, that the propagation of waves of light through the ether was explainable only on the theory of *transverse* displacement; the propagation of sound waves, on the other hand, is due to alternate condensation and rarefaction of the grosser air, rarefaction succeeding condensation at intervals, of course, of half the wave lengths, making longitudinal waves.

Then—becoming enthusiastic over his subject—forgetting for the moment the so-called "popular" nature of his address and his audience—discarding his written notes—he gave a momentary glimpse, to those who could keenly and understandingly follow his intellectual flight into these higher ethereal regions of the inmost (perhaps prophetic) thought of the astute philosopher; and he exclaimed somewhat as follows:

"What is this thing we call the luminiferous ether?

"It is the one thing in all nature we are sure of; that is, the reality and the substantiality of the luminiferous ether.

"I have shown you the diagram of transverse waves of light; may there not also be *longitudinal* waves in this ether, having unknown powers, of which, at present, we have no conception? I am not prepared to say that it is so—this is little more than a scientific dream of mine; yet we cannot say that the luminiferous ether is *not* capable of longitudinal vibration; indeed, I cannot conceive of its incapability, if it be in the least degree compressible; and, while I do not venture to make an assertion at this moment that we will have a new development of force in the future that will be explainable on the theory of longitudinal vibrations of the ether, I think some of us now present may live to see that, though I may not."

While I believe that I have, in the main, correctly recalled these fleeting expressions, unfortunately not recorded at the time, you must not, of course, hold Lord Kelvin responsible for the accuracy of my unaided memory.

This all-pervading (although purely hypothetical) luminiferous ether, an imponderable medium, unaffected by gravity, so far as we know, having great rigidity and elasticity, the only conceivable material connecting link between ourselves and distant worlds, is now regarded by modern philosophers *as the key-note, or the fundamental principle, or genesis of all matter;* indeed, the greatest leaders of thought in this realm of pure science no longer hesitate to attribute all the varying properties of matter to "motion of molecules" of this universal medium. Lord Kelvin said, for example: "What we call matter may be only the rotating portions of something which fills the whole of space, *i. e.*, vortex motion of an everywhere-present fluid," and in his famous address at the Montreal meeting of the British Association* some years ago, he still further elaborated the same thought, and said: "It is scarcely possible to help anticipating, in idea, the arrival at a complete theory of matter in which all its properties will be seen to be merely attributes of motion."

At the present moment we are lost in a sea of speculation, regarding the nature of the new "X ray" shadowgraphs of Professor Röntgen, and in almost a nervous condition of excitement as to the possible future developments; but we have been led by these theoretical and mathematical studies up to a level of comprehension of their possibility.

A word in concluding may serve to explain Professor Himes' doubt as to the presence of X rays in the Crookes tube. He asks: If aluminum is transparent to these rays, why is a shadow cast upon the end of a tube by an aluminum cross interposed in the path of the cathode rays? I think an explanation is this: Aluminum is only comparatively, not absolutely, transparent to these rays. This is proven by the shadowgraphs of aluminum coins thrown upon the screen a few moments ago. Had the metal been *perfectly* transparent, the faint silhouette of the coin would not have appeared at all upon the sensitised plate.

The more intense fluorescent light at the end of the tube in those portions exposed to the full glare of the cathode rays (or to the unshielded bombardment of molecules) would naturally disguise any fainter fluorescence which might otherwise be visible within the shadow of the cross, due to the impingement, within this penumbra, of fewer molecules; or, in simpler words, to the partial leaking through the aluminum cross of cathode or X rays.

---

*Steps toward a Kinetic Theory of Matter. Proceedings B. A., 1884.

The cross is pivoted on a hinge, and when it is thrown down, so that the entire end of the bulb is exposed to the cathode rays, behold! the image of a luminous cross appears on the glass bulb, shining much brighter than the surrounding portions of the fluorescent glass. This is commonly explained, by Professor Crookes and others, on the theory of "fatigue." May it not be due to normal fluorescence of the glass under full exposure, plus the fainter fluorescence caused by leakage of cathode rays, due to partial transparency or permeability of the aluminum?

The gradual fading of the cross from view is explicable upon either theory.

PROF. M. B. SNYDER.—It was far from my intention to have anything to say at this time regarding the important discovery of the action of these rays; but since I have been so cordially invited to participate in this discussion, a few observations may be allowable. The chief interest of Röntgen's admirable discovery lies, it seems to me, not in the proposed practical applications, however important those may come to be, but rather in the bearing it may have in forwarding more accurate theoretical conceptions of the whole question of radiant energy. While it is not desirable, in this discussion, to go into detail concerning any opinion regarding the theory of these phenomena, I may say that I have no manner of doubt that these Röntgen radiations do not require the supposition of the character of longitudinal vibrations. They are, in all probability, but a part of the vast series of electro-magnetic vibrations with which we are already acquainted in the magnetic, heat and light spectra. This would, of course, give them the character of transverse waves. The longitudinal vibration of the ether must be reserved, it seems to me, for gravitation itself. We do not, unfortunately, at the present time, possess a mechanical theory of the ether that is even fairly satisfactory, but the indications, as developed by Lord Kelvin and others, suggest that there is nothing yet known that should prevent us from regarding these rays as a part of the vast electromagnetic gamut. Their refraction, reflection, and even polarisation, would then be a probable result of the future experiments.

An important element in the Röntgen experiment seems to be the transformation of energy that takes place at the surface of the tube, and this has suggested the reflection that we are in all likelihood laying too slight an emphasis upon the changes that take place in the solar radiations within our own atmosphere, changes that may be analogous to those we see in this experiment. The radiant energy of the sun is of one character in space, and of another character within our own atmosphere, just as the action within the Crookes tube is one thing, and that without it another. So, although this is not the time to moot and discuss the mechanical conceptions we should assume, it is, I hope, not beside the question to insist that, however fascinating the applications may be, it is in no less degree fascinating to attempt to provide for this new discovery a proper place in relation to the accepted scientific conceptions. It is even possible that the world-wide interest aroused by the experiments of Röntgen may expend itself in working out a truer conception of radiant energy than has as yet been at all deemed possible.

PROF. GEO. F. STRADLING.—From what I have been able to learn on the subject of this evening's paper, the observers disagree on some points. Professor Frost, of Dartmouth College, for example, finds that his rays found no difficulty in passing through crossed tourmalines; while Dr. H. C. Richards, of the University of Pennsylvania, finds that tourmaline is quite opaque to his rays. Röntgen regards aluminum as a good transmitter, while Professor Frost finds it to transmit poorly. May it not be that there is some marked difference in the rays, at present the subject of so much discussion and speculation? Perhaps one experimenter is using Lenard rays, the other Röntgen rays.

MR. CHAS. H. RICHARDSON.—Mr. President, I would like to ask Prof. Houston a question. When using the Crookes tube connected, as he describes, to a Tesla high-frequency coil, which is connected to a Ruhmkorff induction coil, the latter charged from the street alternating current, is one pole or electrode distinctly negative, the same as when the Crookes tube is directly connected to the Ruhmkorff coil and energised from a battery, or do both poles give the cathode ray?

PROF. HOUSTON.—Each pole of the Crookes tube gives a cathode ray.

MR. RICHARDSON.—That is, the alternations are so rapid that each electrode appears as if it were the negative electrode?

PROF. HOUSTON.—Yes; there are two fluorescent surfaces of the tube, one due to each electrode.

MR. RICHARDSON.—Mr. President, in conclusion, I would like to make a statement. In one of the letters read to-night, I think from Prof. Thomson, is a suggestion of a visual apparatus for use with the X rays, consisting of a dark tube coated inside with some fluorescent substance which could be placed to the eye and directed towards the Crookes tube.

Such a tube has already been designed and made by Professor Magie, of Princeton University. The rough model consisted of one section of a spy-glass, with the lens removed, and one end covered with a piece of black card-board. The inner surface of this card-board disc was coated with barium-platino-cyanide.

When this apparatus was held to the eye and directed towards the sun, no light could be seen in it; but if pointed towards the active Crookes tube and held close to it, the card across the lower end lighted up with a light green hue, and any object opaque to the X rays, held between this tube and the Crookes tube, would cast a black shadow on the card.

I saw the outline of a key and also of the human finger. A gentleman present said he could see the outlines of the bones inside of the outlines of the finger, but I could only detect a heavier shadow in the center of the finger.

DR. KENNELLY.—I have listened, with great pleasure and interest, to the remarks that have been read this evening from different parts of the country, and made by different members of this audience. I think it would be evident, from the differences of opinion manifested in these remarks, that our present knowledge of the nature of Röntgen rays is very limited. I think, however, there can be no doubt that, with so many able workers in different parts of the world, engaged upon the investigation of these rays, it will not be very long before our knowledge of them will be greatly extended. The surprising feature about these rays is that they are produced under conditions which must have been present at any time during the last ten years to nearly every experimentalist in electricity. Nearly everyone having an induction coil and Crookes tube at his disposal has made those marvelous experiments by which Crookes has manifested the behavior of the cathode rays. Throughout all the trials and experiments of this sort, which have been made in this and other countries since the advent of the Crookes tube, these Röntgen rays have, in all probability, been developed, and have been patiently waiting for discovery. It is those things which lie immediately before our eyes that are often so hard to find.

Stated Meeting, December 18, 1895.

MR. JOS. M. WILSON, President, in the chair.

AUTOMOBILE VEHICLES.

BY PEDRO G. SALOM.

The subject of automobile vehicles is almost as old as the locomotive, and, indeed, may be said to be contemporaneous with the locomotive, as all automobile vehicles are, in the truest sense, locomotives. But the fundamental distinction between the two is that one is designed for operating on a rail, while the other is designed for operating on a road or pavement. With the advent of the steam engine, it was natural to suppose that the question of moving vehicles would receive consideration. And so it did; for, as early as 1827, Goldsworthy Gurney built and operated a motor vehicle run by a steam engine, a picture of which I will show you later on the screen.

The subject has been revived by the marvelous results obtained in France, in the two contests which have recently been held there. In the last race, between Paris and Bordeaux and return, a motor vehicle, equipped with a Daimler motor, covered the distance of 750 miles in a little over forty-eight hours, at an average speed, including stops, of nearly 16 miles per hour.

I may be pardoned for reading a short sketch by John T. Bramhall, in *Leslie's Weekly* of December 19, 1895, which, in a charming and concise form, gives a description of the early attempts to introduce automobile vehicles:

"It is a curious circumstance that the horseless carriage is one of the most ancient of ideas. Homer tells us how, when Thetis went to Vulcan with her prayer for a shield for Achilles, she found the lame architect hard at work, bathed in sweat from the heat of his forges.

> "That day no common task his labor claimed,
> Full twenty tripods for his hall he framed,
> That, placed on living wheels of massy gold
> (Wondrous to tell), instinct with spirit, rolled
> From place to place, around the bless'd abodes,
> Self-moved, obedient to the beck of gods."

Milton speaks of

> " * * * * the barren plains
> Of Sericana, where Chineses drive
> With sails and wind their canny wagons light."

The Earl of Worcester, among his "century of inventions"—inventions which, like Keely's motor, always lacked the one prime element of practical success—may have had an automobile carriage. But if he had, it was in the same uncompleted state as the tripods of Vulcan. It never "went." It is certain, however, that, in 1759, Dr. Robinson called the attention of Watt to the possibility of constructing a carriage to be driven by a steam engine, and ten years later, Cugnot, a French army officer, rigged up a gun-carriage and a big copper boiler so that it was driven by its own power. There was too much danger of the passengers being scalded to death to make the machine at all popular, and being convicted of an aggravated assault upon a stone wall, it went with other crude experiments

> "Into a limbo large and broad, since called
> The Paradise of fools."

Watt patented a road engine in 1784, and about the same time, Murdoch, his assistant, completed and made a trial of, a model locomotive driven by a "grasshopper engine." This is said to have run 6 to 8 miles an hour. The earliest patent for road engines in America was that secured by Oliver Evans, who obtained, in 1786, from the Maryland Legislature, a monopoly for his system of applying steam to the propelling of wagons on land. In 1804, he completed a flat-bottomed boat for dredging the Philadelphia docks, and, mounting it on wheels, drove it by its own steam engine to the river bank. Launching the craft, he propelled it down the river, using the engine to drive the paddle-wheels. Thus Evans' "Oruktor Amphibolis," as he named his machine, was the first automobile wagon and the first steam paddle-wheel boat in America. A reproduction of the "Oruktor Amphibolis," and of the Cugnot wagon also, may be seen at the Field Columbian Museum in Chicago.

The illustrations of the various automobile vehicles which will be thrown upon the screen have been sufficiently well described in various previous publications as to be familiar to readers who are interested in the subject, and require no further comment from me.

Mr. Morris and myself first took up the question in June, 1894. At that time little or nothing had been done in this country or abroad, which we could use as a criterion for our experimental work; we were, therefore, compelled to attack the subject in all its bearings from an entirely novel standpoint.

In designing the first vehicle, the primary object to attain was a vehicle which should be able to propel itself through any of the streets of our city, irrespective of their suitability for motor-vehicle traction; because if this object had not been attained, the first criticism would have been that such a vehicle might be useful under ideal conditions of road surface, but for practical every-day life it would not be successful. We, therefore, sacrificed the most important features considered by carriage makers as absolutely essential in order to made a motor vehicle successful, such as weight, design, size and distribution of machinery. As a consequence of this sacrifice, our first vehicle, while not presenting an attractive appearance to a carriage builder's eye, has accomplished all and more than we expected of it.

We got this first vehicle in operation August 31, 1894, since which time it has been in constant use, except during the winter months, and has traveled several hundred miles without serious mishap or accident, all over the streets of Philadelphia, some of which are still in very bad condition for mechanical traction, and through parts of Fairmount Park; and, up to the present time, we have never been compelled to attach a horse to it to bring it home, for any reason whatsoever.

The total weight of the vehicle, including the battery, without passengers, is 4,250 pounds. The weight of the battery is 1,600 pounds. The maximum mileage on one charge is 50 to 100 miles, according to speed and grades. The maximum speed attained is 15 miles per hour. Number of accumulators, 60 of 100 ampère-hours capacity each. Electrical capacity of battery, 13 horse-power hours at maximum discharge rate. The motor is a nominal 3 horse-power "Electric Launch Type," built by the General Electric Company, and capable of developing, for a short time, as much as 9 horse-power. The motor weighs 300 pounds.

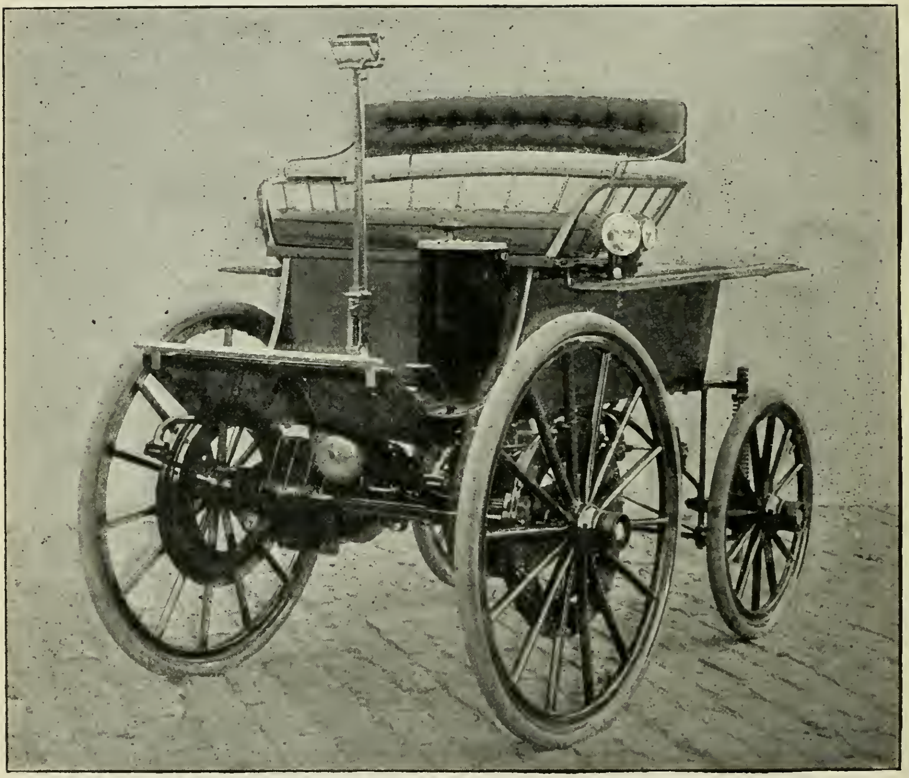
The motor is connected, through a pinion on the end of the motor shaft, to a secondary or countershaft, having a balance gear to enable the wheels to move independently in turning curves. This countershaft has, on the ends, pinions gearing into large gears attached to the rear wheels of the wagon. The front of the wagon rests upon a fifth wheel, of 30 inches diameter, which is attached by an iron frame to the rear axle. The lower half and revolving part of the fifth wheel rests on the springs between it and the front axle. This fifth wheel turns on hardened steel balls, being moved by a pinion and shaft with suitable reducing gear, which is operated by means of the hand wheel on top of the shaft, thus securing ample power, as well as facility in steering.

The controller regulating the current is placed in front of the footboard and operated by shaft and crank immediately below the steering wheel.

The vehicle has a seating capacity for six, but there is ample power, if seats were provided, to carry from twelve to fifteen people. The wheels are ordinary heavy wagon wheels, without ball bearings and with iron tires.

The experimental data obtained from the operation of this vehicle proved conclusively that on good pavements we could propel a vehicle weighing, with passengers, 5,000 pounds, 10 miles an hour, with an expenditure of energy of not over 3½ horse-power or $\frac{7}{10}$ of a horse-power per 1,000 pounds. With this information and the experience gained by operating this first vehicle, we were ready to start in to construct a second vehicle to compete in the "*Times-Herald* Motocycle Contest," with results which have proved highly satisfactory, not only to ourselves, but also to the engineering world.

Our "Electrobat No. 2," which competed in the race on November 28th, and which is designed to carry four passengers, including the driver, weighs only 1,650 pounds, complete with batteries, which you will notice is a substantial decrease over the first one constructed. It presents a very handsome appearance, and, at first sight, one is not sure it is not some new style of surrey. No machinery of any kind is in sight, with the exception of the steering lever, and it is exempt, therefore, from the criticism generally passed on motor vehicles, that they look more like a piece of machinery than a pleasure carriage. The body was built by the Chas. S. Caffrey Company, of Camden, N. J., one of the most famous carriage concerns in the country. There are two "Lundell" motors, of nominal 1½ horse-power capacity each,



Morris and Salom Electrobat. No. 2.

attached to the front axle, and pinions on the armature shafts gear directly into the driving gears attached to the front wheels. The steering is accomplished by turning the hind wheels parallel with each other from a point about 3 inches inside the plane of the wheels, and connected by a rod to a vertical lever of a convenient height, to be operated from the front seat of the carriage.

Although at first sight it might be supposed that steering from the rear would be more difficult than steering from the front, and, notwithstanding the concensus of opinion among carriage men was decidedly opposed to rear steering, yet, as a matter of fact, this has not been found to be the case, as the carriage can be moved, with the slightest effort on the part of the driver, and with the greatest certainty, in any direction desired, and can be turned completely around in a circle of 20 feet in diameter.

The wheels are of wood, and of the usual construction, except that they are fitted with pneumatic tires and ball bearings. The question of the desirability of using pneumatic or cushion tires on a vehicle of this weight was considered very carefully, and here again the carriage men were decidedly in favor of the cushion tire; but, desiring to be abreast of the times in all details that could add to the efficient and successful operation of the machine, we decided to risk the use of pneumatic tires. Our experience so far, while limited in this regard, justifies us fully in having taken the risk, and we feel absolutely convinced that, with some slight modifications, the pneumatic tire is decidedly the best for motor vehicles.

The driving or front wheels in the case of this particular machine are 40 inches in diameter, and the rear, or steering wheels, 28 inches in diameter.

The batteries were furnished by The Electric Storage Battery Company, of Philadelphia, and consist of four sets of twelve cells each, having a normal capacity of 50 ampère-hours per cell. They are grouped in boxes, and so arranged that they can readily and quickly be pushed into place inside of the body of the carriage, connection being automatically made with the controller. The actual time required to take out one set of batteries and replace them with another is less than two minutes.

The controller is a small instrument, standing in a convenient position vertically in front of the seat, and is operated by means of a small hand-wheel on top. There are three speeds ahead and one backward, which are obtained by various groupings of the batteries and motors in series and parallel. The carriage has a maximum speed of 20 miles an hour on a good road or street pavement, and the capacity of the battery is sufficient to propel it from 25 to 30 miles.

Up to the present time, we have used only two different styles or types of battery, and it is our purpose to adhere, in the future, if possible, to one single type, irrespective of the size of the vehicle or the character of work required; and we will obtain the different requirements for varied service by changing the number of cells used on the vehicle, and by various methods of grouping the same through the controller. The type that we have fixed upon is a 50-ampère-hour cell, weighing about 13 pounds complete. Twelve of these cells are grouped together in a single box or tray, with brass plates on the sides for automatic contacts. These boxes or trays of batteries represent, at the maximum rate of discharge, exactly 1 kilowatt hour, or $1\frac{1}{3}$ horse-power hours, and, as they weigh only about 160 pounds each, they can readily be handled by two men; four such boxes or trays are sufficient to propel an ordinary delivery wagon, weighing about 1,000 pounds, 25 or 30 miles.

We believe that the most practical application to which these vehicles can be put, at the present time, is for service in parks and as delivery wagons. We do not consider it practicable, at the present time, to send out such vehicles broadcast over the country before any proper arrangements have been made for their intelligent care and maintenance. We think that the proper plan for their introduction is to construct a sufficient number of vehicles of one kind to warrant the building of a charging station, where the batteries can be charged and the vehicles kept when not in use. This will enable a systematic and intelligent inspection of the various parts of the machines, such as all mechanical contrivances require, and will prevent all the troubles that would naturally arise from inexperienced persons handling and operating them.

The various parts of the machines can at first be purchased and then assembled at the station. This will permit of securing the best talent in the several lines of industry, which go to make up a complete machine. The carriage builders will build the bodies, the electrical manufacturing companies the motors, and so on through the list. A building in a suitable central locality can be purchased or leased, and the vehicles can then be operated either on a lease or rental plan, very similar to the manner in which a livery stable is at present conducted, thus assuring to the owners or lessees a complete and reliable service, such as they could not secure at first by attempting to operate the vehicles themselves. After becoming sufficiently familiar with their operation and the cost of conducting the same, the lessees will then be justified in making their own personal arrangements.

The station would be equipped with dynamos for charging the batteries, and with a sufficient amount of machinery to make all necessary repairs and renewals of motors or batteries. Of course, after fifty or one hundred such vehicles get into actual daily use, their introduction, we believe, will be as rapid, and the growth of the business as marvelous, as that of the bicycle.

While we have made no close estimates as to the cost of manufacturing in quantity, we believe that ordinary delivery wagons can be constructed for from $600 to $800, and pleasure carriages from $1,200 to $1,500; while for larger vehicles or special designs, the prices will vary as much as they do in the ordinary carriage business at the present time.

The magnitude of the business and the possibilities which it may assume in the future can best be considered by comparing the work that is now done with horses, and that which could be accomplished by motor vehicles. At the present time there are probably no less than 100,000 horses in Philadelphia. It costs to keep these horses, on an average, including feeding, shoeing, harness and depreciation or life of the horses, not less than $1 per day, or, in round numbers, about $30,000,000 a year. The work they do could be accomplished by motor vehicles at an expense not to exceed 50 cents a day, or about $15,000,000 a year, thus making a net saving in this one city alone of $15,000,000 per annum. Such a statement as this settles forever the question of good roads or good streets, as it is not contended that motor vehicles would be eminently successful under conditions that can scarcely be tolerated with animal traction at the present time. No further argument would be necessary for the rapid and permanent improvement of all streets and roads in the country, as the enormous saving that would be effected by the introduction of motor vehicles would repay the taxpayer ten-fold in a few years. They would want not only good roads, but also perfect roads, and each city would vie with its neighbor in getting the most excellent pavements that could be laid. Ideal pavements for a city being a heavy bed of solid cement from curb to curb, and as nothing but rubber tires would be used, and as the wear and tear upon the pavements would be practically nothing, it would pay every city in the Union to effect a loan to build colossal subways capable of taking care of all the underground work, so necessary and essential in large cities, and make a permanent pavement above.

The introduction of electrically propelled vehicles will open up an entirely new and immense field for the use of storage batteries, and as The Electric Storage Battery Company, of Philadelphia, controls all the basic patents for the manufacture and use of storage batteries, the new industry about to be launched will greatly increase the volume and magnitude of its business.

Electrobat No. 3 might be said to be a study in automobile design, as may be seen when the picture is thrown upon the screen. It is merely a skeleton or framework, upon which almost any kind of wagon or carriage body can be placed. The design, which is entirely the work of Mr. Morris, is new, and differs radically from anything of this kind ever constructed.

The frame consists essentially of two tubular rings, spaced apart by tubular struts, and forming convenient attachments for the springs and front axle, leaving ample space for the motors and their attachments. At the rear of this frame and attached to the cross-struts is a truss frame, forming the support for the battery and resting on the hind axle, which, in this case, is provided with a "Crawford" universal fifth wheel. This construction admits of various modifications to suit the peculiarities of different styles of vehicles. This vehicle is steered from the rear wheels by means of a lever or other gear, as may be found most convenient. It is of tubular steel construction throughout, and the wheels are built on bicycle principles, having steel spokes and pneumatic tires and ball bearings.

The method of gearing and general operation of the machine is similar to that of the large Electrobat No. 2, above described.

This machine has a maximum speed of about 20 miles per hour, the complete weight, with batteries, being 1,180 pounds. It was built by the Crawford Wheel and Gear Company, of Hagerstown, Md.

Electrobat No. 4 was built for the purpose of demonstrating the practical application of electric traction, with storage batteries, to existing types of vehicles. The standard tubular gear of the Crawford Wheel and Gear Company, of Hagerstown, Md., was selected, and, with the slight modification in the rear axle of an additional tubular shaft on which to suspend the motors, and the addition of a steering gear, is precisely what it is now selling, and what is generally known as the Crawford Pneumatic Run-About Wagon. "These gears are made of weldless steel tubing, shaped like the ordinary side bar and axle. The axles are arched or dropped to correspond with the height of wheel used. The connections (with the exception of the fifth wheel) are brazed as if in one piece. There are no bolts, clips, nuts, etc., to loosen and rattle, and positively no joints except necessary working parts. It has ball-bearing spindles and steel-spoked wheels, with pneumatic tires with 'Crawford non-creeping device,'" being the lightest electrical road machine ever built. It has a maximum speed on levels of over 15 miles per hour, and a distance capacity of from 20 to 25 miles.

	Pounds.
The gear weighs	50
Wheels	64
Body	86
Battery	350
Motors	150
Controller and plate gears	50
Sundries, about	50
Total	800

THE DISTINCTIVE POINTS OF ADVANTAGE POSSESSED BY THE ELECTRICALLY-PROPELLED VEHICLES ARE AS FOLLOWS:

(1) Absolute safety.
(2) No noise.
(3) No vibration.
(4) No heat.
(5) No odor.
(6) Simplicity of construction.
(7) Ease of handling.
(8) Perfect control.
(9) Cleanliness.
(10) Economy of power.
(11) Economy of operation.
(12) Cost.
(13) Elegance of design and freedom from mechanical appearance.

Considering these points in their order--first, as to safety. A vehicle propelled by storage batteries is absolutely free from danger to life or property. Can the same be said of a gasoline vehicle carrying from 8 to 10 gallons of gasoline? Would you be permitted to store such an amount of gasoline in a barn or stable without forfeiting your insurance; and would not the general introduction and handling of such vehicles, by inexperienced persons, result in a loss of life and destruction of property? Can a vehicle using such a fuel be considered to have general utility and adaptability?

Would it be practicable to operate delivery wagons, say of Adams Express Company or any other large corporation, having hundreds of wagons at their barns or stations, and store sufficient gasoline, amounting to thousands of gallons, to operate them all? This is a vital point, as no system can be properly considered to have general utility which is handicapped by its own inherent dangers.

(2) As to noise. The electrical vehicle is almost noiseless. It does not begin to make the noise that even a horse makes on a dirt road, while a gasoline vehicle must, perforce, make a continuous puffing noise, due to the exhaust from the motor, and this is not only disagreeable, but to some people alarming.

(3) Vibration. Owing to the rotary action of an electric motor, no vibration of any kind is communicated to the vehicle, whereas, in a gas or gasoline engine, which is operated by the explosive force of gas or vapor in a cylinder, there is a constant jarring and vibration, due both to the explosions and to the rapid reciprocating motions of the piston and rod and its connections through a crank to the fly-wheel.

(4) Heat. As there is no fire or consumption of fuel in any way on an electrical vehicle, there is, of course, no heat developed; but in a gasoline vehicle, the constant ignition and explosion of the gasoline raises the temperature of the cylinder to such a point on a long run as to prevent lubrication of the cylinder, and to endanger the successful operation of the motor. To prevent this trouble, water circulation is necessary, and very often even this is not sufficient, and ice in quantity has to be carried in order to keep the cylinder cool enough to allow the motor to perform its normal work.

(5) Odor. Of course, there is absolutely no odor connected with an electrical vehicle, while all the gasoline motors we have seen belch forth from their exhaust pipe a continuous stream of partially unconsumed hydrocarbon in the form of a thin smoke with a highly noxious odor. Imagine thousands of such vehicles on the streets, each offering up its column of smell as a sacrifice for having displaced the superannuated horse, and consider whether such a system has general utility or adaptability!

(6) Simplicity of construction. Aside from the æsthetic considerations above enumerated, the electrical vehicle

admits of a simplicity of construction which it is impossible for a gasoline vehicle ever to attain. No engine, gas or steam, was ever built that at all approaches in simplicity an electric motor, and when such a motor is geared direct to the driving wheel by a single pinion on the armature shaft, it would seem that the very last degree of refinement in simplicity of construction had been reached in the electrical vehicles under consideration. Compare this construction with the marvelously complicated driving gear of a gasoline vehicle, with its innumerable chains, belts, pulleys, pipes, valves and stop-cocks, etc., and then put the question—Is it practicable? Is it not reasonable to suppose, with so many things to get out of order, that one or another of them will always be out of order? Does so complicated a structure possess the elements of general utility and adaptability?

(7) Ease of handling. The last point considered naturally brings us to the next feature, ease of handling. With so complicated a mechanism as that described above in the case of gasoline vehicles, it would be absolutely essential to have a skilful engineer and machinist to operate them. While it might be possible to instruct an ordinary man or woman how to steer the machine and to put on or take off the power, yet, for its successful operation, this would not be sufficient, as it would be imperatively necessary for them to be familiar with any or all the troubles that would naturally arise from imperfect mixture of the air and gas, or the proper amount of gasoline necessary to feed into the mixture, and, in fact, to possess a working knowledge of the various parts of an engine and how to keep them lubricated and in proper working condition; whereas, on an electrical vehicle, we can take a boy twelve or fourteen years of age, or a young lady accustomed to driving a horse, and, with ten minutes' practice, they can operate the vehicle perfectly. Of course, we do not mean to claim that no technical knowledge is required in connection with electrical vehicles; on the contrary, the proper care of batteries requires skilful and intelligent workmen, but such work is independent of the operation of the vehicle, and is, in fact,

done when the vehicle is not in use. Once place the charged batteries on the vehicle, and you are ready to start without any complicated conditions being complied with.

(8) Perfect control. This point has to do with the steering apparatus and the method for regulating the speed of the vehicle. While a safe and certain method of steering is essential in a motor-vehicle, there are many ways of accomplishing the same result. We have employed three different methods, all of which work satisfactorily. The regulator for controlling the speed is worked with the left hand, and the current can be turned on or off instantly, and the vehicle brought to a standstill by a brake worked by the foot, and then, if so desired, made to go backwards. The steering is accomplished by the right hand, and can be done with the nicest degree of accuracy in any direction.

(9) Cleanliness. This point properly belongs to the æsthetic condition first mentioned, but the electrical vehicles enjoy a marked advantage in this respect over their gasoline competitors.

(10) Economy of power. It is proper for us to state that we do not believe any of our competitors can show such small losses of power for internal work as we do in our machines. As a result of this, we are able to do the same work with a smaller expenditure of energy. For example, during the tests of our vehicles which were made in Chicago, we developed a speed of over 20 miles per hour with an input to the motors of less than 3 horse-power.

(11) Economy of operation. As to this point, the cost of operating a motor-vehicle by either electricity or gasoline is so small as to be almost negligible, or, in our case, ¼ cent per mile.

(12) Cost. In the matter of cost, we feel that we can decidedly underbid the gasoline vehicles, on account of the much simpler form of our construction. For example, the vehicle under test can be sold at a handsome profit for from $1,200 to $1,500.

(13) Elegance of design. This last point, while the least important of all those discussed, should be given its due proportion of merit. This is a matter that must necessarily

be left to the carriage builder; but, owing to the extreme simplicity of the mechanical equipment of an electrical vehicle, compared with a gasoline motor-vehicle, it would seem as though it would be a much easier problem for the carriage builders to solve.

From a table published by the Equitable Electric Railway Construction Company, as to the horse-power necessary to propel 1,000 pounds, at various speeds and up various grades at same speed, I find that, on a level rail, at 12 miles per hour, it requires 0·320 horse-power per 1,000 pounds. While we have had but little opportunity to test our new machines, it is interesting to compare the few readings which we have already obtained with this table. These readings have all been obtained from Electrobat No. 2. Assuming the weight of vehicle and two passengers to be about 2,000 pounds (1,650 pounds of vehicle and 350 pounds passengers), the horse-power required for speeds Nos. 1, 2 and 3, on levels, is as follows:

Speed.	*Ampères.*	*Volts.*	*Watts.*	*Miles per Hour.*	*Horse-power.*	*Horse-power on Rails.*
1	6	96	576	5	·77	0·266
2	15	96	1,440	12	1·90	0·64
3	30	90	2,700	20	3·63	1·066

Trautwine gives 91 pounds as the tractive effort required to move a ton 10 miles per hour, on levels; this is equal to 2·4 horse-power. As we have been able to move a ton 12 miles per hour with 1·9 horse-power, we must attribute the increased efficiency obtained to pneumatic tires and ball bearings.

DISCUSSION.

DR. ROB'T GRIMSHAW.—What is the weight on drivers?

MR. SALOM.—About 1,000 pounds.

MR. JOHN H. COOPER.—The most important feature, for which no adequate provision seems to have been made on the machine exhibited here to-night, is the importance of controlling its speed while descending grades and for sudden stoppages, to avoid accidents by collision. In a hilly country, safety going down hill is as important as ability to go up the same. Of course, on good roadways, like the avenues in Chicago, the ordinary brake may answer the purpose of a check or stoppage, provided the wear and tear on the tires does not too rapidly destroy them. If iron tires, as now used, be adopted for certain kinds of service, the brake, as usually made and applied, may become the cheapest and most readily applied method of arresting the motion of these vehicles, and that, upon all roadways, whether level or undulating.

I would suggest for the consideration of Mr. Salom, as a feature which I believe to be worthy of experiment, a modification of the *motor*, such that it may become a *dynamo*, and thus return to the batteries (while the vehicle is propelled by gravity in descending grades) a part of the motive force which was expended in ascending. As the change of electric current could be made instantly and easily, and perhaps with less first cost of mechanism to accomplish the desired result, there would seem to be no reason why such a method of controlling speed should not be adopted. The chief advantage of this method would, perhaps, be the partial restoration of electromotive force to the batteries, by which, in many journeys, the machines would be enabled to get back home again, without extraneous assistance.

In general, with such devices, the amount of motive force necessary for any round trip will be measured as for the same on a level roadway; the extra expenditure of force to ascend would be nearly restored by the returned force developed by the descent.

With such devices you would obtain as full control of stopping motions as you now have of guiding, both of which are absolutely necessary in crowded thoroughfares, as well as on hilly roads.

MR. SALOM.—The use of the motor as a dynamo to develop current for charging the batteries in descending grades is quite an old one, but the additional advantage gained would not compensate for the complications involved in accomplishing such a result.

DR. GRIMSHAW.—What about the brakes? Experience shows that on long grades the ordinary brake applied to a bicycle tire will ruin it very shortly. On some of the long Virginia hills, if a rider loses his pedals, and must control by the brake, the tire is often ruined in one "coast."

Mr. Salom.—The question of braking is one that will not have to be considered very seriously until motor vehicles become more largely introduced for country service. The ordinary brake device, with which the present vehicle is equipped, is amply sufficient for any grades that may be encountered in a city like Philadelphia, and, indeed, is quite sufficient for very steep grades, if the speed of the vehicle is not allowed to become too great before the brake is applied. The ability to reverse the machine, moreover, is another source of braking, which could be used in any emergency to avoid accidents. For very steep grades, it would, perhaps, be better to have a band brake applied on the armature shaft.

Dr. Grimshaw.—How quickly can the machine be swerved from a straight course? In close quarters an intelligent horse will swerve and avert a collision before his driver will receive and weigh the impression and pull the proper rein, and the horse receive and act on the impression. It is often promptness, rather than accuracy of guidance, that is essential.

Mr. Salom.—In regard to steering, or swerving from a straight course quickly, when going at a high rate of speed, I would say that the machine responds to the motion of the steering lever instantly, and it would seem that the ability to avert collision would be largely a matter of the personal equation of the driver, some minds acting very much more quickly than others.

Mr. Wm. L. Dubois.—I would like to ask Mr. Salom whether he has made any estimate as to what it would cost a user of a vehicle to operate it after all arrangements for storage house, etc., as proposed, shall have been completed.

Mr. Salom.—The cost of operating such a vehicle as we have exhibited here this evening, when proper arrangements for its care and maintenance had been made, would not exceed 50 cents a day for 25 miles.

Dr. Grimshaw.—Isn't $1 a day a liberal estimate for keep of horse? At expensive stables in New York City, the charge for boarding a horse and caring for harness and wagon is only $30 a month.

MR. SALOM.—In regard to my estimates for the expenses of animal traction, I would say that I arrived at the figure of $1 per day per horse, after consulting with a great number of persons who use horses to a greater or less extent; and while, of course, $1 would be a very liberal estimate where a large number of horses were employed, yet it so frequently exceeds this amount in the case of private individuals, who have only a few horses, that I think the average would be above, rather than below, this amount.

MR. DUBOIS.—In the case of an electric carriage, if the owner of it should choose to lie off for a month, it would then be costing him nothing, while the expense of keeping a horse would continue.

MR. SALOM.—What Mr. Dubois says is quite correct, and the total cost of operating would be much less than I have estimated, where the vehicle is only occasionally operated, or where the service is irregular in its application. We had a good illustration of this last summer, when, owing to the heat, our first experimental wagon was not taken out of the station for nearly three months, the batteries having been charged immediately after the previous trip had been made, and, although nothing had been done to the vehicle or the batteries for that length of time, we were enabled to back the machine out of the station and make a run of 15 miles, at the rate of 10 miles an hour, without any additional charge being put into the batteries, or without the necessity of doing anything to the machine.

MR. C. J. REED.—What is the capacity of the battery, when charged, in horse-power hours?

MR. SALOM.—About 5 horse-power hours, at maximum rate of discharge.

MR. SPENCER FULLERTON.—What difficulties have you met from the prejudices of the community, or from the prejudices of the authorities? Has the latter prejudice led to the enactment of absurd laws against automobile vehicles, restraining their natural and proper development, as has been the case in England? For example, liability for damage caused to or by frightened horses, would be one point; others are: increased rates over horse-drawn vehicles on toll roads; responsibility for injury to roads and bridges; unnecessarily wide tires, enforced in the case of the automobile, etc.

MR. SALOM.—We have met with no difficulties from the prejudices of the community, nor have we found that our vehicles would frighten horses. It is very rare that a horse pays any more attention to our vehicles than he would to an ordinary carriage. Of course, some horses occasionally show evidence of being a little frightened, but no runaways have ever been caused, nor has any accident of any nature whatever happened, from the operation of these vehicles in the streets or park. Up to this time no restrictions of any nature whatsoever have been put in force against the motor vehicle.

ELECTRICAL SECTION.

Stated Meeting, Tuesday, January 28, 1896.

MR. CARL HERING, President, in the chair.

THE EVOLUTION OF THE STORAGE BATTERY.

BY MAURICE BARNETT.

In 1801, Gauterot, while decomposing salt water electrolytically, noticed that on breaking the circuit he could obtain a current of short duration from the electrodes. A few years later, Ritter constructed a pile consisting of disks of copper, separated by pads moistened with saline solution. After passing a strong electric current through the pile he was able to obtain a current of considerable intensity from the pile itself.

This pile of Ritter's, while not a storage battery in the sense in which that term is now used, was, in principle, related to the modern apparatus employed for the so-called storage of electric energy. It is interesting to us as being a piece of apparatus, the theory of which would, at a later date, have served as the basis for a generalisation which would have led to the inception and development of the storage battery. But the time was not ripe for this. To have been anything else than a scientific curiosity, the means must have been at hand for charging storage batteries cheaply. The cheapest source of charging current then known was that obtainable from primary batteries, which, on the ground of cost, prohibited the use of secondary cells. But there was another circumstance that retarded the advent of the storage battery—a circumstance founded on a misconception, which, at the beginning of the century, led investigators astray and caused them, in their desire to improve the primary, to ignore the secondary battery altogether. To appreciate this, consider the following experiment:

If we place two platinum electrodes in dilute sulphuric acid, and connect these with some source of direct current of sufficiently high E.M.F. to decompose the solution, the disengagement of gas at the negative and positive poles will at once be noted. If now the circuit be broken, and the wires leading from the electrodes be connected with a galvanometer, the needle of the galvanometer will be deflected—showing that an electric current is passing.

To-day we account for the reverse current produced in such an electrolytic cell, by saying that, during the decomposition of the solution, hydrogen and oxygen are dissociated. As soon as dissociated, they tend to recombine, and, in recombining, cause a counter E.M.F. equal to that required to effect the dissociation. It is the manifestation of this E.M.F. which causes the passage of the reverse current. Three-quarters of a century ago this was not fully understood. In the case of the Ritter pile, it was assumed that, during electrolysis, the salt was decomposed into acid and base, and that these, on recombining, produced a current. In the case of the electrolysis of pure water, or dilute sulphuric acid, with platinum electrodes, there was neither acid nor base to recombine, nor oxidation at the electrodes, to produce an electric tension; hence, investigators, looking about for causes, ascribed the action to physical, rather than to chemical, agencies. In this particular case, the electrodes were said to be "polarised," and the term "polarisation" was adopted to define the phenomenon itself.

If the early investigators of the galvanic battery had had the acumen of Gaston Planté, storage batteries would have been developed at an earlier date. Planté, it will be remembered, studied polarisation phenomena in order to utilise them. The other investigators studied to eliminate them.

Towards the end of the first half of this century, it was demonstrated that non-oxidisable electrodes, as platinum, which had been placed in oxygen and hydrogen gas respectively, would, when immersed in dilute sulphuric acid, give a current just the same as if they had been used in the electrolysis of the acid itself. This was the principle of the Grove gas battery, described in 1842 by Sir W. Grove. It is the earliest form of reversible battery that was recognised as such, and is thus of considerable historical interest. It was not possessed of qualities that would make it valuable as a storage battery, although, in principle, it embodies some features which would be meritorious in any storage battery. There are, however, practical reasons why the battery is not adapted to the needs of modern engineering.

In 1859, Gaston Planté began the researches which were to secure to the world an eminently practical invention; and for the first time, the phenomena of polarisation were made the subject of an inquiry looking to their utilisation.

Planté's investigation had in view the discovery of the behavior of different metals in an electrolytic cell. To this end, he electrolysed dilute sulphuric acid with rods of the various metals used successively as electrodes. Two to three Bunsen elements furnished the requisite E.M.F. to decompose the solution. After passing a current for some time, he disconnected the primary battery and studied the reverse current obtained from the electrodes. Of the metals used, some exhibited very slight electric capacity, *i. e.*, they furnished only a very transitory current; others exhibited considerable capacity. Of all the metals tested, he found that lead gave the greatest promise, not only on account of its capacity, but also because of the intensity of the discharge.

In a primary battery, chemical action is concerned in doing both useful and useless work, the relative amounts of which will depend, among other things, on the nature of the electrodes. This useless work is a result of local action, by which a large amount of metal is acted upon without the production of external current. It is not too much to say that over nine-tenths[1] of the useful energy of a battery may be dissipated under some conditions by this local action, even on closed circuit, without the production of anything but heat and myriads of little currents that will play over the surface of the electrodes without entering the outer circuit.

One of the worst features of local action is that it is greatest on open circuit. With storage batteries, which may be left for weeks at a time on open circuit, it is easily seen how energy, once stored up, might be dissipated without any useful result. Here, then, it becomes absolutely essential that the electrodes should be of such a nature as to prevent, as far as possible, all action except that identified with the production of external current.

It is very plain that metals forming soluble salts are most likely to show the greatest losses in this direction, because, as fast as they dissolve, new surfaces are exposed, which permit further useless corrosion. One of two things is therefore necessary: either we must have insoluble electrodes, or the electrodes, during discharge, must form salts insoluble in the electrolyte.

As we survey the various metals that might be utilised in storage batteries, one after another will have to be discarded. Zinc, iron, and even copper, which, on account of the energy they develop during chemical action, would be even more efficient than lead, weight for weight, are objectionable on the ground of the solubility of their salts. Lead, on the other hand, furnishes salts which are practically insoluble in the electrolyte. The influence which this insolubility exerts in diminishing local action is apparent on momentary consideration. The peroxide and the metallic lead of the positive and negative plates, respectively, are both converted into sulphate during discharge. The same reaction takes place as a result of local action. Now, as this sulphate forms, it gradually encloses the remaining active material, and protects it from further oxidation.

---

[1] See *Proc. Roy. Soc.*, xxxvi, 1884.

Again, the fundamental principle of the storage battery is the possibility of reversing the physical and chemical changes which take place during each discharge. With soluble electrodes, the difficulty that lies in the way of the redeposition of the metal in an efficient form seems almost insuperable. Up to the present day, effort after effort has been made to accomplish this, but without anything like a satisfactory result. The consequence is that recourse has been had to electrodes which are either insoluble, or which, like lead, form salts insoluble in the electrolyte.

At the present time, lead is the only metal used to any extent in the manufacture of storage batteries. Zinc and copper have been used with lead in what are known as the Reynier and the Sultan cells, while zinc has been used with copper in the Thomson-Houston and the Waddell-Entz cells. This departure from the lead type of battery has not been attended with success. Lead seems to be the only metal of which it can be said that it is easy to reproduce *both* the physical and chemical changes which take place in the electrodes during discharge. And not only that, but this reversal may be repeated and repeated an indefinite number of times, year after year, without the cell showing signs of excessive deterioration. This is what has made the use of lead imperative, up to the present time, and has made the manufacture of the lead storage battery successful where other types have been failures.

This merit of lead, in being susceptible to regeneration, grows out of the insolubility of its sulphate, already spoken of as being an important factor in preventing loss of energy due to local action. Two other properties of lead also adapt it for use in the construction of storage batteries. The first is that the lead peroxide used in the positive plates has excellent conducting qualities, and that the couple formed of spongy lead and lead peroxide furnishes, in an electrolyte of dilute sulphuric acid, a high E.M.F.

Having thus reviewed, rather hastily, the reasons why lead is preferable to other metals in the construction of accumulator plates, we can understand why Planté, pursuing his investigations in 1859, with a view of utilising polarisation effects, should have concluded that lead seemed best adapted to yield these effects in the highest degree, and should have selected this metal in the construction of his accumulator.

From the illustrations in text-books on natural philosophy —and especially in the older treatises—everyone has been made familiar with Planté's spiral accumulator, which consisted of two plates, placed concentric with each other, in dilute sulphuric acid; one plate being lead, the surface of which was peroxidised; the other, metallic lead. These constituted an electric couple, which gave an E.M.F. of approximately 2 volts.

Having constructed his accumulator, Planté set about to determine the best method of "forming" the plates, that they might yield effects extending over a considerable interval of time. The procedure he adopted was to pass a current through the accumulator, first in one direction, then in the other, and so on, with intervals of rest in between. The effect at first was merely superficial; but after reversing the current and repeating the process a sufficient number of times, the metal was affected to a considerable depth, and, on the completion of the action, one electrode would be covered with a thick layer of spongy lead, and the other with a thick layer of peroxide. In such a form the electrodes were capable of furnishing currents of great density for a length of time depending on the extent to which the plates had been affected by the electrolytic processes to which they had been subjected.

It is very evident that "forming" plates by the process just described not only consumed much time, but was also attended with considerable expense, owing to the fact that the only current available for this work was that obtainable from primary batteries. These circumstances operated to prevent anything more than a theoretical interest being taken in the subject.

Between 1859 (when Planté began his experiments) and 1880, when Faure invented the pasted battery, great changes had taken place in the condition of the electrical arts and manufactures. The dynamo electric machine had, by this time, been perfected, and offered the means for the cheap production of currents of great density and high E.M.F. This circumstance put the storage battery on a different footing, and held out promise of the utility it would enjoy with the further development of the electrical arts.

Faure's invention was the outcome of efforts to reduce the cost and minimise the time factor in the Planté process of "forming." To this end, he made pastes of minium (red lead) and litharge—oxidised compounds of lead, represented, respectively, by the chemical formulæ, Pb_3O_4 and PbO—which he applied to the surface of the positive and negative plates. When these were subjected to the "forming" process, the red lead was oxidised to peroxide and the litharge reduced to spongy lead, with a material saving in time and costs over the Planté process of producing corresponding changes in solid lead plates.

Scarcely had the Faure plate been brought out than accumulators were put to a variety of industrial uses, amongst which may be mentioned their application to carry the day load in lighting stations and to prevent the necessity for running dynamos at night in private residences. The practicability of charging accumulators, when this could be conveniently done, and discharging them at pleasure, either alone or in conjunction with dynamos, was a very inviting possibility, which was taken advantage of from the very outset. It was also frequently suggested to employ some central stations exclusively for charging accumulators, to be distributed afterwards to furnish light and power. Even for traction purposes, where accumulators are subjected to the severest demands, their use was proposed as far back as 1880. In that year, experiments were begun, looking to their utilisation in this field, and in 1883, a car went into service at Kew Bridge, London. This car was equipped with a Siemens dynamo, set to run as a motor, and about 4,000 pounds of batteries.

As might have been foreseen, the storage battery was put upon the market in a crude and undeveloped form before it had been sufficiently studied by the chemist and physicist and improved by the manufacturer; and, in addition to this, it was applied to a variety of purposes, for which, in its early form, it was notoriously unfit. The result was that, in nearly all of its various applications, it proved a failure—a circumstance that has had a great deal to do with creating a prejudice against storage batteries, which to this day has been ineradicable, although secondary cells, as now constructed, are vastly superior to the crude forms of 1880, and are in successful operation in hundreds of interesting applications, where their use is, in every case, attended with satisfaction. To-day, the extension of the use of the storage battery is looked on with growing favor.

Modern storage batteries date from the invention of Faure, and 1880 marks the year when their commercial applicability became assured. Up to within a few years the pasted lead battery was the only form of storage battery in use to any extent. Recently the Planté type of battery has again come into favor, together with an improved form of battery known as the chloride accumulator. These are all lead batteries, and differ from one another only in the method of their construction and formation.

In the following paragraphs these three types of lead batteries will be considered in the order named.

Planté batteries are made in diverse forms. In the first place, there are the solid plates with striated surfaces. Then there are the various forms of laminated plates, where the greater part of the body of the plate consists of ribbons of lead. Then, again, there are other forms where porosity is given to the lead by kneading it hot with some porous material, which may afterwards be dissolved out. These various forms are all subject to innumerable modifications.

The objects aimed at by increasing the surface of the lead per pound of material, are: first, to facilitate the forming process (it is easy to see that the more surface there is, the more lead will be exposed to the electrolyte, and the more quickly will electrolytic action accomplish the requisite formation); second, to increase the capacity of the plates, *i. e.*, the ampère-hour output per pound of the elements; third, to permit changes of volume to take place in the active material without prejudice to the life and efficiency of the cells.

The method of forming the plates, *i. e.*, bringing the negative to the spongy lead, and the positive to the peroxide state, varies with the place where the process is carried on. At some works these changes are brought about by the old Planté process. This method, proving tedious, has been superseded by an electro-chemical treatment, by which the plates are brought into the desired state much more quickly than by electrolytic action pure and simple.

The characteristics of the Planté type of battery are: capability of giving heavy discharges without sustaining injury, minimum local action and general freedom from the irregularities due to local action.

Up to within a few years, the pasted battery monopolised the attention of inventors and supplied the needs of those using secondary cells. It superseded the Planté battery at the start, because it offered the means whereby plates could be quickly formed, which would possess large capacity for a given weight of elements, and be capable of momentary heavy discharges without being much injured.

The Faure, or pasted battery, is made by applying a paste of lead oxide (minium, Pb_3O_4, for the positives, and litharge, PbO, for the negatives) to perforated or solid "grids." Now, if two such plates be used as electrodes in a bath of dilute sulphuric acid, and the bath be decomposed, the liberation of hydrogen at the negative pole will reduce the litharge to spongy lead, while the liberation of oxygen at the other pole will oxidise the minium to lead peroxide.

So great an improvement was the Faure battery supposed to be over that of Planté, that between 1880 and 1890 it was thought, generally, that no commercial storage battery could be made that was not of the pasted type. It is only necessary to examine the early forms of Faure batteries to see that they fall far short of being an even approximately perfect medium for the storage of energy. When such cells go into service, local action is set up between the active material and the grid, because of the imperfect contact between them. This, among other things, leads to loss of the charge of the battery. This contact is rendered still more imperfect with time, by reason of the sulphate of lead, which forms and insulates the active material from its support. Moreover, in the active material, which is an ordinary mechanical mixture, expansion takes place in every direction; and as no allowance can be made for taking up this expansion, the result is that the cohesion of the particles—already weak—is weakened still more by the strains occurring within the mass itself. Under the influence of poor contact with the grid, and lack of cohesion of its particles, the active material has a tendency to fall away from its support, short-circuiting adjoining plates and producing irregularities which soon bring the usefulness of the cells to an end.

One form of modern pasted plate requires particular mention. It is known as the Tudor positive. This plate is heavy and thick, with surface channelled so that the active material will find better support. Red lead as a paste is applied to both sides of the plate, which is afterwards formed by electrolytic action. This type of battery is widely used, and has qualities which specially adapt it for central station work. Thus, it is capable of yielding its entire charge in one or two hours. Now, as the maximum demand in a central station lasts for an hour and a half, or at most for four hours daily, it is found to be considerably cheaper to install storage batteries rather than direct generating machinery, to take care of this extra load. For this special work Tudor batteries are very largely used. As illustrating the great value they possess as an auxiliary of dynamo machines, it may be stated that in Prussia and Austria they are found in 80 per cent. of the central stations, in numerous railway plants, and in thousands of isolated lighting plants.

The "chloride" battery takes its name from the fact that the active material of the plates is made from lead chloride, rather than from metallic lead, as in the Planté, or lead oxide, as in the pasted batteries. Without going too much into construction details, it will suffice to say that lead chloride is cast into small pastilles with beveled edges. These, spaced in moulds, have antimonial lead cast around them under pressure. The resulting plates, alternating with sheets of zinc, with which they are in dead-short-circuit, are then placed in a solution of chloride of zinc, and allowed to remain until the zinc chloride has been dissolved out and the lead brought to a metallic state. Close examination of these plates reveals the fact that the active material is porous and of fine crystalline structure. Positives are formed from these plates by electrolytic action.

The claims made for this type of battery are: (1) that good contact between the active material and the support is assured by the beveled edges of the original chloride tablets and the lead forced around them under pressure; (2) that the crystalline formation of the active material permits changes of volume in these masses to take place, without producing any strains within the masses themselves; (3) that the cohesion of a crystalline mass is always greater than that of a mechanical mixture; (4) that the porous condition of the active material secures large capacity per pound of elements; (5) that the porous condition of the active material facilitates the "forming" process. These claims all seem to be substantiated by the performance of "chloride" cells, which show a high efficiency in practice, very small deterioration (and therefore small cost for maintenance), capability of holding charge over considerable intervals of time, and freedom from short-circuiting, buckling, sulphating, or any of the troubles to which the old lead batteries were subject. They are thus seen to possess none of the defects of pasted batteries, while they embody all the merits of the Planté cells without their faults of structural weakness and tedious formation. In one sense they are Planté cells, but differ from this type in that the lead for the active material is prepared separate from the rest of the plate. "Chloride" negatives are said to be the best negative plates produced up to the present time, and are frequently used with positives of other types in storage battery installations.

DISCUSSION.

MR. C. J. REED.—There are some questions raised in this very interesting and instructive paper which seem to me of great importance, and on which I am unable to agree with the author.

The first question to which I refer is that of the process of reduction of lead from lead sulphate in charging the accumulator. This reduction is stated by the author—and is generally stated by others—to be effected by the action of nascent hydrogen. In other words, it is held that the electric current first decomposes the solution, liberating hydrogen and oxygen; that the hydrogen reacts on the lead sulphate of the negative plate, producing metallic lead and sulphuric acid, while the oxygen at the positive plate acts upon the lead sulphate and water, producing lead peroxide and sulphuric acid.

It seems to me that no evidence has ever been adduced to substantiate the theory of this double reaction, and that we have every reason to believe that the charging of the accumulator results directly in the electrolysis of lead sulphate on both plates. If oxygen and hydrogen are produced as a first step by the current, we have no way of knowing it, since the gases are not evolved. The only gas evolved is that which escapes, except the small amount that becomes occluded in the porous mass. Neither the occluded portion, nor that which escapes, can perform any further chemical action. The only portion that could perform any reduction is that portion which is not evolved at all, and of the liberation of which we can have no knowledge.

The supposition that the electric current would decompose the solution more easily than the lead sulphate is entirely gratuitous. There is every reason to believe, however, that it would decompose the lead sulphate more easily than the solution.

The formation heat of PbO is 55,350 calories, corresponding to an electromotive force of 1·19 volts; that of H_2O is not less than 68,360, corresponding to 1·47 volts. The formation heat of H_2SO_4 (assuming $H_2,O=68,360$ and $SO^3,H_2O=21,320$) is 89,680, and that of dilute sulphuric acid 107,530 calories, corresponding respectively to 1·93 and 2·22 volts; while that of $PbSO_4$ is only 75,552 calories, corresponding to 1·63 volts. It is known, also, that H_2O is not an electrolyte and could not be decomposed.

It is evident, therefore, that, whether we consider the reaction to be a decomposition of the oxide or the sulphate, it will require a greater electromotive force to liberate hydrogen than lead. There is no more necessity or reason in supposing the lead sulphate requires nascent hydrogen for its reduction than there is for supposing that copper is reduced from copper sulphate in electro-plating by the action of nascent hydrogen.

Another sufficient proof that there is no primary decomposition of H_2O or H_2SO_4, is, that if the hydrogen were more easily reduced than lead by electrolysis, the hydrogen so reduced would not be able to reduce the lead. It is merely a question of whether lead or hydrogen has the greater heat of combination per electro-chemical equivalent. The figures given above, and which are generally accepted as correct, ought to settle this question.

This explains satisfactorily why a discharged accumulator does not gas at the beginning of the charge, particularly with a small current. There is in the discharged accumulator an excess of lead sulphate accessible to the action of the current, and the current is all employed in doing useful work, decomposing lead sulphate on both plates, the reaction being as follows:

$$\overset{\text{Pos. Plate.}}{PbSO_4} + 2H_2O + \overset{\text{Neg. Plate.}}{PbSO_4} = Pb + PbO_2 + 2H_2SO_4$$

As the charging proceeds, the lead sulphate is used up, and the current, which must continue to perform an equivalent amount of electrolytic work, necessarily decomposes some of the solution, evolving free oxygen and hydrogen. This also explains why a higher electromotive force is required to send a given current through the cell at the end of the charge than at the beginning; and it explains also why a large charging current in a cell of small active surface produces, even at the beginning of the charge, a large amount of electrolytic gases.

Furthermore, the only products of discharge that have ever been found are, as stated by Gladstone and Tribe, H_2SO_4 and $PbSO_4$, the latter mixed in varying proportions with PbO_2 on the one plate and with Pb on the other. The only lead products of the charging process that have ever been found are lead and lead peroxide. Under some circumstances there is formed in the solution some H_2O_2, O_3, and $H_2S_2O_8$, but no lead persulphate, or any other compound of lead except the peroxide. If any lead persulphate were formed incidentally in charging, it would immediately be dissolved in the solution, and could no longer be considered a part of the active material of the electrode. Its gradual spontaneous decomposition would cause a white precipitate of lead sulphate in the bottom of the cell. But to consider such a product as the normal result of charging an accumulator, or as an intermediate step in the formation of lead peroxide, is out of the question. If such were the case, the active material of the positive plate would all go into solution the first time it was charged. The only lead persulphate known to exist is so highly soluble that it can be brought into the solid state only by evaporating its solution in vacuo.

The second question raised in this paper, on which I am unable to agree with the author, is the statement that an insoluble active material is necessary or desirable in an accumulator in order to prevent local action. It seems to me that any insoluble coating that prevents local action must do so by preventing chemical action. It would, therefore, prevent the normal action of charge and discharge in the same degree that it prevents local action. This is one of the things that is certainly not desirable in an accumulator.

Local action is not due, I believe, to the contact of the active material and solution, but to the existence of local galvanic couples. If these can be removed without insulating the solid from the liquid portion of the active material, that would seem to me a better method. This local action is illustrated in the primary zinc battery. Zinc, even chemically pure, immersed in dilute sulphuric acid, will be dissolved by the galvanic action of local couples due to differences in density of adjoining parts, or the junction of crystalline and amorphous particles. By thoroughly amalgamating the zinc, its molecules are brought into solution in the mercury, and the surface thereby rendered homogeneous. Local action is in this manner entirely prevented.

I believe, therefore, that an accumulator having no insoluble coating to incrust and insulate the active material would be more nearly the ideal than one in which the reactions are encumbered by a solid insulating product.

The author of the paper states, very truly, that the difficulties of the lead-zinc accumulator arising from the spontaneous discharge by local action on the zinc plate, have, up to the present time, proved insuperable. It cannot be denied, however, that, if its difficulties could be removed, it possesses certain advantages, as stated by Mr. Barnett, over the lead type. It gives a considerably higher electromotive force, and can be made much lighter for a given capacity.

As to the difficulty caused by local action, this seems to me not entirely insurmountable. I have experimented to some extent on this problem, and have found that, by proper management, it can easily be controlled. I find no difficulty in producing an accumulator of this type which will, with very large surfaces exposed, retain 50 per cent. of its charge for about two months. As a matter of fact, the discharge of the peroxide plate seemed to be more rapid than that of the zinc plate. When we consider that for many purposes it is desired to retain the charge of an accumulator only a few hours, the loss is reduced to a small fraction of 1 per cent., which is practically negligible. I believe, therefore, that there is a large field of usefulness for this type of cell.

MR. BARNETT.—In denying the reduction of lead sulphate by means of hydrogen, Mr. Reed adopts a view of the changes taking place at the negative electrode, which he will find difficult to prove—namely, that the electrolytic decomposition of $PbSO_4$ is accomplished without the agency of hydrogen, and that the electrolyte is not decomposed until the above-mentioned electrolysis of $PbSO_4$ has been effected. In support of his view he cites thermo-chemical data to prove that, inasmuch as the heat of formation of $PbSO_4$ is less than that of H_2SO_4, the former compound will be decomposed more easily than the latter, and that this reduction will take place before any gas is evolved, as a result of the electrolysis of the solution.

If Mr. Reed's figures were correct, his contention on this point might be justifiable; but, whereas he gives 75,552 c. g. calories as the heat of formation of $PbSO_4$, I find that the value of this quantity, taken from the "Thermo-Chemical Memoirs" of Thomsen, is 145,130 c. g. calories—a value nearly twice as large as that given by Mr. Reed. Obviously, $PbSO_4$ will require for its decomposition a higher E.M.F. than H_2SO_4 would require to resolve it into its molecular constituents, which would go far to prove that the solution *is* electrolysed before the $PbSO_4$ is reduced.

But, continues Mr. Reed, even if the hydrogen were more easily reduced than lead by electrolysis, the hydrogen so reduced would not be able to reduce the lead, for the energy of formation of $PbSO_4$ being greater than that of H_2SO_4, hydrogen could not possibly reduce lead out of the former compound. But it must not be forgotten that, in addition to the affinity of (H_2) for (SO_4), there is the E.M.F. of the cell acting in conjunction with the affinity of this hydrogen molecule. And just as (SO_4) can unite with H_2SO_4 to form $H_2(SO_4)_2$ (persulphuric acid) under the proper E.M.F. and density of current, although this compound *absorbs* heat in its formation, so we can understand that (H_2) can unite with the (SO_4) of the lead sulphate, even if energy is absorbed in this operation.

If Mr. Reed is right in stating that the electrolytic decomposition of $PbSO_4$ at both plates precedes the decomposition of the solution, how does he account for the fact that PbO_2 is formed at the positive electrode *from the beginning of the charge*, showing that the electrolyte was decomposed from the very outset, else, whence would the oxygen have been derived wherewith to effect this peroxidation? Furthermore, if hydrogen does not participate in the reduction of $PbSO_4$, and is not occluded, it should be evolved earlier in the charging process than oxygen, for the oxygen first given off is absorbed at the positive plate in forming peroxide. But in spite of this fact, oxygen is given off earlier in the charging process than is hydrogen. As oxygen cannot be liberated without the simultaneous liberation of hydrogen, what, it may be asked, becomes of the hydrogen liberated while PbO_2 is being formed in the earlier stages of charging? The answer is that it is concerned in uniting with the (SO_4) of the $PbSO_4$ at the negative plate, to reduce metallic lead and regenerate the H_2SO_4 that participated in the discharge reactions.

The electrolytic decomposition of $PbSO_4$ pure and simple is a more difficult matter than the gentleman imagines. Dr. Lodge and Lord Kelvin objected originally to the lead sulphate theory of the action of the accumulator, because of the impossibility of reducing lead sulphate, and even Gladstone and Tribe showed that it was only partially reduced after days of electrolytic action.

With regard to the possibility of lead persulphate participating in the reactions of charge, there is nothing in the nature of this compound to preclude such a reaction taking place, as the conversion of $PbSO_4$ into PbO_2 by means of the intermediate formation of lead persulphate. Even admitting the solubility of this compound, it must be remembered that it is decomposed the moment it forms. Its solution and dispersion through the electrolyte is an impossibility. Barium chloride is a soluble salt; but if we had electrodes of $BaCl_2$ in an electrolyte of dilute sulphuric acid, no one would say that $BaCl_2$ would be dissolved and dispersed through the electrolyte. It could not exist in the presence of free sulphuric acid. In the same way lead persulphate is supposed to represent an endothermic compound, formed in the course of electrolysis, but decomposed as fast as formed, with production of PbO_2 and regeneration of H_2SO_4.

In Volume 59, of the *Journal of the Chemical Society*, London, I find, in a contribution from the chemical laboratory of the University of Edinburgh, by Hugo Marshall, the following details of an experiment:

"If PbO be rubbed up in a mortar with a saturated solution of ammonium persulphate, considerable quantities of ammonia are liberated, but in a short time the mixture darkens from formation of PbO_2, and on treating with H_2O and filtering, no soluble salt of lead is found in the solution." Now, the explanation of this reaction is that the PbO decomposes the ammonium persulphate, with formation of water, lead persulphate and ammonia, as shown by the following equation:

$$(NH_4)_2\,(SO_4)_2 + PbO = Pb\,(SO_4)_2 + H_2O + 2(NH_3)$$

This lead persulphate is acted on by the water liberated, and also that derived from the air, which results in formation of lead peroxide and sulphuric acid, as shown by the following equation:

$$Pb(SO_4)_2 + 2H_2O = PbO_2 + 2H_2SO_4$$

This explains why no soluble persulphate of lead is found in the solution, for it has been decomposed. In charging an accumulator, $Pb(SO_4)_2$ is only momentarily formed as an intermediate product, and is decomposed as soon as formed, as shown in the above equation. The solubility of the salt does not preclude the reaction taking place, as described above.

Lastly, with regard to the necessity or desirability of having insoluble active material as a preventive of local action, I admit that if it be possible to prevent local action in other ways it may preferably be done; for the use of insoluble electrodes undoubtedly reduces the efficiency of the battery materially by preventing complete chemical action. The use of soluble electrodes is objected to, not so much on account of their liability to local action, as because of the difficulty encountered in reversing, on charge, the physical and chemical changes taking place during discharge. While lead is not a good electrode, especially for negatives, where have we any example, to-day, of cells in successful operation where *soluble* electrodes are employed?

I appreciate fully the limitations of insoluble electrodes, but the fact that storage batteries of the lead type are the only ones of which the manufacture has been technically and commercially successful, would certainly lead one to the belief that no mistake is made in pinning one's faith to this type of cell. Of the numerous modifications of the "Sutton" type of accumulator, consisting of a lead peroxide—copper couple in an electrolyte of copper sulphate; of the "Reynier" type, consisting of a lead peroxide—zinc couple in an electrolyte of zinc sulphate; of the Thomson-Houston type, which is a reverse form of the Daniel cell; and lastly, the Waddell-Entz type, consisting of porous copper oxide and metallic zinc in an electrolyte of potassium zincate —can Mr. Reed point to any of these in successful operation to-day?

When the difficulties attending the re-deposition of metals in an efficient chemical and physical form have been worked out, there will be no reason why soluble electrodes should not be employed to advantage in constructing accumulators. But to-day these difficulties have not been worked out. Local action is only one of the disadvantages attending the use of soluble electrodes. The greatest obstacle to their use is the difficulty of reversing completely, on charging the physical and chemical changes they undergo, during discharge.

Mr. Reed.—It will not be profitable to prolong this discussion by merely arguing established chemical laws and questions of fact. I assumed in my previous remarks that the elementary principles of chemistry were admitted, and that Mr. Barnett had given more particular attention to certain well-recognised chemical laws. It is of no interest to discuss these questions on a basis of arbitrary supposition without any regard to the facts.

The main facts and, in my opinion, the only rational theory of the reaction that takes place in charging a lead accumulator, are to be found in an article by Leibenow, in the *Zeit. f. Electrochem.*, January 5, 1895. They are in substance the same as stated in my previous remarks.

As to the statement accredited to Thomsen, that the heat of formation of $PbSO_4$ is 145,130, this may be a typographical error or some other mistake; or the statement may be based on some misunderstanding of the article quoted. As Mr. Barnett does not give a specific reference, I cannot say which is the case. I am sure, however, that the statement is not correct.

The results obtained by Thomsen and others are stated in condensed form in Watt's Dictionary of Chemistry (old edition, Vol. VII), under the subject of heat. On page 614 the following formation heats are given:

$Pb,O,SO_3Aq = 4 \,.\, 18{,}888\ (= 75{,}552)$

$Fe,O,SO_3Aq = 5 \,.\, 18{,}772\ (= 93{,}860)$

$Zn,O,SO_3Aq = 6 \,.\, 18{,}077\ (= 108{,}462)$

$Mg,O,SO_3Aq = 10 \,.\, 18{,}092\ (= 180{,}920)$

It seems hardly necessary to deny that lead stands midway between zinc and magnesium, as it would according to Mr. Barnett's figures, or that the formation heat of its sulphate corresponds to anything like 3·1 volts. If, as held by Mr. Barnett, the $PbSO_4$ requires this high electromotive force to reduce it, any amount of nascent hydrogen could not do it. From the quotations given above, it will be seen that $ZnSO_4Aq$ requires only 2·33 and $FeSO_4Aq$ only 2·02 volts for reduction. Yet, nascent hydrogen has never been known to reduce these metals to the metallic state. This reduction can be effected only by the absorption of additional external heat, as in a furnace; in the case of iron at a heat of 300° C.; and in the case of zinc, only slowly, at the boiling point of that metal.

The theory advanced by Mr. Barnett that the electromotive force of the charging current is added to the affinity of (H_2) for (SO_4), and that the two, acting conjointly, do the work equivalent to one is certainly new. It amounts to connecting electromotive force and chemical affinity in series in an electrolytic cell. But this theory is not likely to be accepted by any except those who are willing to abandon Faraday's law of electro-chemical equivalents and the law of simple substitution in chemistry, to say nothing of the doctrine of the conservation of energy. It is certain that nascent hydrogen and electric current do not act in that way in any other reduction. In all other cases where nascent hydrogen acts in conjunction with electric current, or any other reducing agent, the result is an amount of metal reduced which is the sum of the amounts reduced by each reagent acting separately, instead of being an entirely different reaction from that produced by either one alone. In other words, several reducing agents mixed together in the same solution always act in parallel and never in series.

If this novel theory were true, it would lead to some very interesting results. We should, for example, be able to produce a single galvanic cell of almost unlimited electromotive force by simply mixing together in a porous cup a great number of strong reducing agents, and outside of the porous cup a great many oxidising agents. The electromotive force of the cell would be the sum of the electromotive forces of all the reagents in the mixture. A Bunsen and a bichromate cell, mixed together, would give an electromotive force of nearly 4 volts, and, by adding a Grove cell to the mixture we could get nearly 6 volts. The only difficulty with this theory is that it is not supported by any facts.

As to Mr. Barnett's difficulty in understanding how PbO_2 can be formed by the electrolysis of $PbSO_4$, I think it is only necessary to remind him that $PbSO_4$ is itself an electrolyte, and the products formed are the same as though no water were present, viz.:

$$\overset{+}{PbSO_4} + \overset{-}{PbSO_4} = PbO_2 + Pb + 2SO_3$$

As the SO_3 cannot exist in the free state in presence of water, we have simultaneously formed $SO_3 + H_2O = H_2SO_4$: or, combining in one equation, we have

$$\overset{+}{PbSO_4} + 2H_2O + \overset{-}{PbSO_4} = PbO_2 + Pb + 2H_2SO_4$$

By writing the symbol of lead sulphate $PbO.SO_3$, instead of $PbSO_4$ and Aq for an indefinite quantity of water, the reaction may possibly be a little more apparent:

$$2PbO.SO_3 + Aq = PbO_2 + Pb + 2SO_3 + Aq$$

The only reaction in which the water is concerned is that of combining with the SO_3 liberated as a by-product.

Pure, chemically precipitated $PbSO_4$ is easily and rapidly changed to PbO_2 and Pb by the electric current, references to the contrary notwithstanding. This may be shown by placing a paste of pure $PbSO_4$ and pure water between lead or platinum electrodes, and passing a current through the mixture. The paste is rapidly converted into PbO_2 and Pb. In this case, at least, there can be no decomposition of the H_2O at the beginning, since pure water is not an electrolyte and no H_2SO_4 is present.

The fact that, in charging, oxygen is given off before any hydrogen appears, is easily explained. The statement that oxygen cannot be liberated without the simultaneous liberation of hydrogen is contrary to all experience. The nature of the ions liberated at the positive and negative electrodes depends upon the electrolytes in contact with each and the working conditions. It is easy, for instance, to liberate, simultaneously, oxygen and either zinc, copper, lead, gold, silver, tin, mercury, or even aluminum, sodium, potassium and barium without any hydrogen.

In the accumulator it is only necessary to suppose that some H_2O_2 is formed along with the PbO_2, and the liberation of oxygen follows necessarily, as these two bodies cannot exist in contact without the immediate reduction of PbO_2 and evolution of oxygen.

It does not seem to me to be necessary to invent improbable theories of chemical reaction in order to explain the formation and decomposition of lead persulphate, when there is no evidence whatever that any lead persulphate is formed in an accumulator, none of it having ever been found.

My remarks in regard to soluble and insoluble active material for an accumulator had reference more to what is desirable than to what has been commercially accomplished. The fact that we have not yet found a commercial accumulator of light weight, or one with a perfectly dry electrolyte, is no indication that it is not desirable. If we are to be content with pinning our faith to what has already been accomplished, and bounding the possibilities of the future by the cobwebs and traditions of the past, then truly we should accept the lead accumulator of to-day as the *summum bonum* and *ne plus ultra*.

MR. BARNETT.—In concluding this discussion, let me say that I quite agree with Mr. Reed that "it is of no interest to discuss these questions on a basis of arbitrary supposition without any regard to the fact." As some importance attaches to the heat of formation of $PbSO_4$, let us direct our attention to that. I regret that I have not a copy at hand of Thomsen's "Chemical Memoirs," and that I cannot cite the reference requested; but on page 40 of Gore's treatise on the "Electrolytic Separation of Metals," the heat of chemical union of $PbSO_4$, in c. g. calories, is given as 145,130. Referring to this value, Mr. Gore states, at the beginning of the table, that the figures are taken from the Memoirs referred to.

Mr. Reed's contention that this value is too high is not supported by any facts adduced by him. It may be of interest to cite here the chemical formula of the discharge of the lead accumulator, with the corresponding heat of formation of the substances produced. Mr. Reed will then see that there is no ground for doubting the accuracy of the figure for the chemical heat of formation of $PbSO_4$ given by me. We may write the electrolytic equation of the action of the lead accumulator as follows:

$$\begin{array}{l} (2.PbSO_4) + (2H_2O) - 2(H_2SO_4.19H_2O) + [(\text{Electrolyte} + 2(19H_2O + H_2O)] - PbO_2 = 90920 \text{ c.g. calories} \\ 290260 \quad + \quad 136720 \quad - \quad 277280 \text{ app.} \quad + \quad 3520 \quad - 62300 \end{array}$$

This, according to the method followed by Sir W. Thompson for calculating E.M.F. from thermo-chemical data, corresponds to the development of a pressure of *2 volts*, which is the normal pressure of the lead accumulator. It is thus seen that the heat of formation of $PbSO_4$, as given by me, is not at all at variance with the facts observed in the performance of secondary lead batteries.

I may add that I have not advanced any theory connecting the E.M.F. of the charging current "in series" with chemical affinity. All I have done is to posit sufficient E.M.F. to decompose the electrolyte and effect the ordinary combinations taking place during the charging of the cell. With such an E.M.F. in operation, which, by the way, is sufficient to decompose $PbSO^4$, hydrogen is generated at the negative plate simultaneously with the development of the electrical tension on $PbSO_4$, which tends to break up that compound; and when that compound is broken up, I maintain that the (SO_4) *is not transported to the positive plate, but unites, then and there, with the hydrogen liberated to form hydro-*

gen sulphate. Mr. Reed seems to be wrapped up in the contemplation of those compounds only which yield heat during the combination of their constituents. It might be well, therefore, to remind him that there are "endothermic" compounds (or those that *absorb* heat when their constituents unite) as well as "exothermic" compounds, which *give out* heat when their constituents unite. It does not, therefore, make any difference whether the heat of formation of H_2SO_4 is less or greater than that of $PbSO_4$; if the E.M.F. of the charging current is capable of decomposing $PbSO_4$, then the hydrogen generated at the negative plate will unite with the (SO_4) as long as any $PbSO_4$ remains. This is not opposed to any law enunciated by Faraday, and is in the strictest accordance with the laws of the conservation of energy and the correlation of forces.

Respecting Mr. Reed's unwillingness to accept the view that the E.M.F. of the cell *can* determine a chemical reaction which involves the *absorption* of heat, I can only say that he can point to no authority that will coincide with him. In 1878, Berthelot discovered persulphuric acid, and showed that it was the primary product at the positive electrode when dilute H_2SO_4 was electrolysed. According to Mr. Reed, such a compound could not be formed during electrolysis of H_2SO_4, because it *absorbs heat.* Mr. Reed knows that, in charging an accumulator, there is consumed nearly 20 per cent. of energy in excess of what is needed to overcome electrical resistance. Does it not occur to him that part of this is used in effecting endothermic combinations?

If the E.M.F. needed to charge lead accumulators were capable of decomposing $PbSO_4$ *without decomposing the electrolyte*, such a reaction as Mr. Reed represents,* *i. e.*,

$$\overset{+}{PbSO_4} + 2H_2O + \overset{-}{PbSO_4} = PbO_2 + Pb + 2H_2SO_4$$

would take place. But, as a matter of fact, the charging current is always capable of decomposing the electrolyte. I think, therefore, that I am not at variance with scientific opinion when I state that, when hydrogen is formed at the negative plate, it unites with the SO_4, which is simultaneously liberated there.

---

* See page 316.

If we reject this view, we must consider that when the electro-negative (SO_4) of the $PbSO_4$ is attracted to the positive pole, the electro-positive (Pb) is attracted to the negative pole. Under continual charging, the negative plate ought to have deposited on it an amount of lead which is only limited by the existence of the positive plate. This view is absurd, yet Mr. Reed is logically led to it by insisting on the pure and independent electrolysis of $PbSO_4$ as being concerned with the charging reactions of the lead accumulator.

Franklin Institute

[*Proceedings of the stated meeting, held Wednesday, March 18, 1896.*]

HALL OF THE FRANKLIN INSTITUTE,
PHILADELPHIA, March 18, 1896.

Vice-President H. R. HEYL in the chair.

Present, 164 members and visitors.

Additions to membership since last report, 11.

The Actuary transmitted the report of the judges appointed by the Board of Managers to examine a memoir submitted in competition for the "Boyden Premium," by an author writing under the pseudonym "Massis." The decision of the judges was unfavorable to the competitor. The report was received and adopted. [Referred for publication.]

Communications were presented from the following:

Mr. Stogdell Stokes exhibited apparatus for making the Röntgen shadowgraphs, and showed some excellent pictures made by Mr. Leeds and himself.

Mr. F. W. Geisberg, on behalf of Mr. Emile Berliner, exhibited the grammophone in its present commercial form.

Mr. W. N. Jennings showed some interesting photographs of "ribbon lightning," and gave an explanation of this appearance. [Referred for publication.]

The meeting then proceeded to the discussion of the "Filtration of Water Supplies for Cities."

Remarks were made by Dr. Albert R. Leeds, Mr. Edwin F. Smith, Dr. Benjamin Lee, Mr. L. Y. Schermerhorn, Mr. Thos. Shaw, Mr. J. Emory Byram, Mr. J. C. Trautwine, Jr., Dr. Goldschmidt and others.

At the close of the discussion, the following resolution was adopted:

Resolved, That it is the sense of this meeting that the Councils of the City of Philadelphia should make an appropriation sufficient to satisfy the requirements of the Director of Public Works for the erection of an experimental filtering plant.

Adjourned. WM. H. WAHL, *Secretary*.

JOURNAL

OF THE

FRANKLIN INSTITUTE

OF THE STATE OF PENNSYLVANIA,

FOR THE PROMOTION OF THE MECHANIC ARTS.

VOL. CXLI. MAY, 1896. NO. 5

THE Franklin Institute is not responsible for the statements and opinions advanced by contributors to the *Journal*.

THE FILTRATION OF CITY WATER SUPPLIES, WITH SPECIAL REFERENCE TO THE NEEDS OF THE CITY OF PHILADELPHIA.

The subject above stated was announced as the question for discussion at the stated meeting of the Institute, held Wednesday, March 18, 1896.

The discussion was opened by the reading of the following paper:

AN ARGUMENT FOR THE FILTRATION OF WATER DRAWN FROM THE SCHUYLKILL RIVER FOR DOMESTIC SUPPLY.

BY EDWIN F. SMITH, C.E.

The Schuylkill River, at the time when it was first taken for the water supply of the city of Philadelphia, early in the century, flowed through a region heavily timbered with oak, pine and hemlock—an ideal source of supply. About one-sixth of its water shed (310 square miles) is north of the

Blue Mountains, in a country not adapted to agricultural pursuits, and which, at that early day, was almost without human habitations. South of the Blue Mountains the valley of the stream widens, and its broad acres contain one of the most fertile agricultural regions of the State, embracing, above the city of Philadelphia, an area of 1,590 square miles, which, as early as 1800, was fairly well settled by a farming community.

From that day to this, the stream has been gradually changing in character. The discovery of anthracite coal at the head waters of the stream was closely followed by the chartering of the Schuylkill Navigation Company, in 1815, and the building of dams and canals, for the creation of a slack-water navigation. An impetus was given to business of all kinds in the valley, and the little settlements grew to towns and cities. The woodsman's axe was busy, as, unfortunately, it always is in such a country, and in the first half of the century, sad inroads had been made in the noble forests bordering the "hidden river." From that period dates its deterioration.

The pollution of the river above Flat Rock Dam may be said to date from the year 1850. Prior to that, the towns were small and without sewers, and the manufacturing industries, even at Manayunk, had not grown to such a size as to perceptibly influence the purity of the river water. The volume of flow of the stream was large as compared with the inflow of polluted water, but the cutting off of the timber had already begun to effect a change in the flow, the floods becoming more destructive, and the periods of low water more protracted.

Viewing the Schuylkill as a water supply stream to-day, after a period of deterioration of nearly half a century, the change is very marked.

In 1850, there were thirty-two pools formed by the dams of the Schuylkill Navigation, on the 108 miles of river from Fairmount, at Philadelphia, to Port Carbon. These pools aggregated 48 miles in length, and if there is any merit in the theory of subsidence as a means of purification of water, they performed a part in holding back the mineral matter at the normal flow of the river. At the present time, there are nineteen dams in the river, the thirteen remaining ones above the Blue Mountains having been removed, and the river restored to its original channel and natural slope.

The effect of this change upon the water supply of the city of Philadelphia is easily understood. Prior to 1890 steam dredges were constantly at work in the pools of the upper river. removing the deposits of culm washed down from the anthracite collieries, and of sand and debris, resulting from the scouring of the banks of the stream and its tributaries after the cutting off of the timber.

Now, in this 20 miles of river, there is no agency at work to arrest the flow of coal dirt, but instead, when the river is in flood, the work of disintegration of the particles is hastened by the flow over the bed of an open river with considerable declivity. The presence of coal dirt is very perceptible, at Philadelphia, in the black water which comes in every freshet with what is called the second rise of the river.

Below the Blue Mountains, in the second division of the river already referred to, the floods bring down the yellow clays of the limestone regions in Berks and Montgomery Counties, the red shale of the lower tributaries of the Perkiomen and other streams, and the washings from the surface of an extended agricultural district. The chrome-yellow, and at times the reddish color of the water, is a sufficient indication to those familiar with these streams that the lower river is in flood.

These are the elements in the water supplied to the city for domestic purposes that cause discomfort to its citizens and provoke unfavorable criticism as to its purity. But however uncleanly it may be, and *unsuitable* for any domestic and manufacturing purpose, it does not follow that water impregnated with pulverised anthracite coal and with earthy matter is dangerous to health. The unsightly water is not always impure, and the clear, sparkling water is not always a pure and safe one for drinking purposes.

There are, however, sources of pollution in every river flowing through a fertile and well-populated district like the Schuylkill Valley, which must be guarded against in some way, if the health of any community using the river for a domestic supply is to be preserved.

First and most important of these to Philadelphia is the pollution of the river within the city limits.

Much has been done by the city, since the year 1865, to prevent this. The creation of Fairmount Park, the improvement of the Wissahickon Valley, the building of the Mantua Creek sewer on the west side, and the Manayunk intercepting sewer on the east side of the river, the building of river walls on either side of Fairmount Pool—all at a great cost—are indicative of the desire of the people that everything possible should be done to protect and preserve the purity of the water supply. A few more sources of pollution might be removed at a very small cost, namely, the indiscriminate dumping of ashes and refuse into the river at Manayunk, and the flow of sewage through the sewers into Fairmount Pool, in cases where it has not already been intercepted.

Second, the pollution of the river by the towns and cities above Philadelphia.

This has not, up to the present time, been a serious matter, but it may become serious in the near future, unless preventive measures are used.

Seven cities and towns, namely: Reading, Pottstown, Spring City, Phœnixville, Norristown, Bridgeport and Conshohocken, with a total population of 110,000, pump daily (approximately) 11,500,000 gallons of water from the Schuylkill for domestic and manufacturing purposes. They are all equally interested with the city of Philadelphia in preserving its purity. Nevertheless, without the restraining arm of the law, exercised through a State Board of Health, as is done in Massachusetts, Connecticut and a few other States, the purity of the water cannot be preserved. With the multiplication of conveniences of living, and the introduction of modern water appliances into dwellings and public buildings, there comes the demand for sewers, to take the place of cesspools and to carry off waste water. Sewers must discharge somewhere, and there is nothing so easy and apparently so economical in the eyes of a taxpayer as to empty them into the river.

Fortunately for Philadelphia, there has been very little of this evil up to the present time; but it is on the increase, and, in the natural course of events, will grow very fast. Within a year the city of Reading, with a population of 72,000, has completed the sewerage system of its first district, covering about one-third of the city. The sewers, instead of discharging into the river, are connected with a sanitary sewage system, with a disposal plant, and arrangements for burning the excrement and refuse solid matter, and filtering the liquid through sand filter beds, before discharging the effluent into the rivers. *Unfortunately, this system is not at the present time in use*, the sewage being allowed to flow through a by pass directly into the river. Few house connections have as yet been made; but as they are now allowed by the city authorities, the increase in number will be very rapid, and, therefore, in the interest of the towns on the river below, and the city of Philadelphia, it would appear to be wise to limit, in some way, the use of the by-pass. As a matter of ordinary prudence, it is best that crude sewage should be kept out of streams; it is in fact absolutely unsafe to allow it to flow into a stream which, at any point below, is the source of a public water supply.

I have indicated two urgent reasons why the city of Philadelphia should filter its entire supply from the Schuylkill, namely:

(1) To remove sedimentary matter, mineral and organic, and filth brought down by floods, so as to clarify the water and make it *sightly and fit for domestic purposes.*

(2) To remove, as far as possible, organic matter contained in sewage from cities and towns in the valley, which is a constant menace to the health of those obliged to use the water for drinking purposes.

No State in the Union has done more or better work in this direction than the State of Massachusetts, and its example might profitably be followed by Pennsylvania, to whose State Board of Health the Legislature so grudgingly gives inadequate appropriations.

To the State of Massachusetts we are indebted for the solution of two important questions in connection with the filtration of a polluted water supply. I quote from the report of the Massachusetts State Board of Health, for the year 1894, as follows:

"(1) With properly constructed filters, which are carefully operated, at a *uniform moderate rate of filtration* (not exceeding 5,000,000 gallons per acre, daily), satisfactory hygienic results may be regularly obtained with the Merrimac River water.

"(2) The cost of rendering, by filtration, a polluted water supply safe for drinking purposes is *considerably less* than was formerly supposed to be the case."

These statements are based upon the experience gained in operating the sand-filter beds connected with the water supply of the city of Lawrence, Mass. In this connection it may be stated that the valley of the Merrimac is much more densely populated than that of the Schuylkill, and the problem of filtration is a more difficult one.

What is being done at Lawrence with the Merrimac River water can be done at Philadelphia with both the Schuylkill and the Delaware. Filtration is being carried on now throughout the city for both household and manufacturing purposes—and, in some instances, on quite a large scale. I submit the results of a chemical analysis of sand-filtered Schuylkill water drawn from the Market Street main, the filters having a rated capacity of 450,000 gallons per twenty-four hours. This examination is made disinterestedly for the purpose of following up and regulating the working of the filters, and of preserving a record of the condition of the water analysed each month.

The results show the Schuylkill water to be not so bad as it has been represented to be; but, on the contrary, they prove it to be a safe drinking water, if properly filtered.

ANALYSES OF SCHUYLKILL WATER, AFTER PASSING A MORRISON & JEWELL PRESSURE FILTER.—(O. S. DOOLITTLE, CHEMIST.)

	PARTS PER MILLION.						GRAINS PER GALLON.		
	Free Ammonia.	Albuminoid Ammonia.	Chlorine.	Nitrates.	Nitrites.	Required Oxygen.	Organic Residue.	Mineral Residue.	Total Residue.
1894.									
July	0·038	0·066	6·37	0·70	trace	0·34	—	6·89	12·90
August	0·022	0·064	3·90	2·99	·0034	1·90	—	7·98	10·96
September	0·030	0·076	10·38	0·23	trace	1·65	—	7·98	10·40
October	0·026	0·010	5·93	0·16	trace	1·45	—	4·32	6·09
November	0·032	0·100	4·94	0·20	trace	1·75	—	4·98	6·62
December	0·026	0·022	1·08	9·60	trace	0·85	—	4·84	5·56
1895.									
January	0·028	0·032	0·495	1·30	trace	0·95	—	4·10	5·54
February	0·052	0·044	4·95	3·00	trace	1·10	—	5·44	7·49
March	0·045	0·096	4·44	0·70	trace	1·50	—	3·84	4·97
April	0·016	0·068	4·88	0·30	trace	1·45	—	4·83	5·62
May	0·018	0·048	4·95	2·00	none	1·55	—	4·04	6·26
June	0·014	0·060	5·44	4·00	trace	1·25	—	3·19	6·23
July	0·054	0·048	5·44	2·40	trace	2·45	—	—	6·05
August	0·014	0·090	4·94	0·68	trace	1·85	slight	—	6·46
September	0·008	0·066	6·86	0·64	trace	2·25	slight	—	6·53
October	0·046	0·088	7·97	3·60	trace	1·90	slight	—	7·04
November	0·050	0·096	7·50	0·54	trace	2·35	slight	—	7·30
December	0·040	0·058	7·00	1·70	trace	2·15	slight	—	8·08
1896.									
January	0·090	0·033	6·48	2·00	trace	2·175	slight	—	5·57
February	0·160	0·074	6·00	3·00	none	2·20	slight	—	4·85

NOTE.—Sand filtration without the use of alum, from July, 1894, to January, 1895, inclusive. Alum used as a coagulant, from February, 1895, to February, 1896, inclusive.

RESULTS OF CHEMICAL ANALYSIS.

One sample per month of Schuylkill water, for twenty months (July, 1894, to February, 1896, inclusive) from service mains in Ninth Ward, city of Philadelphia, after the water had passed through pressure filters, of a capacity of 450,000 gallons per twenty-four hours, using sand as the filtering medium:

Parts in 1,000,000.	Highest in 20 Months.	Lowest in 20 Months.	Average of 20 Months.	STANDARD OF PURITY.	
				Dr. Leeds' Maximum.*	Proposed Jersey City New Water Supply.
Free ammonia	0·16, Feb., 1896	0·008, Sept., 1895	0·0404	0·12	0·05
Albuminoid ammonia	0·10, Nov., 1894	0·010, Oct., 1894	0·0619	0·28	0·15
Required oxygen . . .	2·45, July, 1895	0·34, July, 1894	1·6532	5·00	—
Nitrates	9·60, Dec., 1894†	0·16, Oct., 1894 May, 1895	1·987	5·00	2·00
Nitrites	0·0094, Aug., 1894‡	None, Feb., 1896	Trace	0·01	None
Chlorine	10·38, Sept., 1894§	0·495, Jan., 1895	5·4972	10·00	8·50

* See Philadelphia Water Department Report for 1883. Page 243.

† Heavy rain fall and flood in river three days preceding the taking of sample.

‡ Sample taken during the period of very low water in the river, extending back more than thirty days.

§ Sample taken following a heavy local storm causing a sudden rise in the river.

The question for Philadelphia is: what shall be done to preserve and enlarge its water supply? The city has even now reached a crisis, and is pumping, in seasons of drought, in excess of the ability of the river to furnish water. For twenty-seven years, since 1869, the question has been before successive administrations, and has been debated in Councils, only to be shirked and handed down to their successors.

I cannot hesitate, therefore, to express my conviction that a great mistake was made in the framing of the "Bullitt" Bill, upon which the present city government is based, in not vesting the control and management of the water supply in a Board of Water Commissioners, instead of in Councils and a cumbersome "Watering Committee" of Councils. Such a board should be non-partisan, and limited in number to four or six members, equally divided between the two leading political parties, with power to use the surplus revenue of the department for the extension of the water works, when necessary.

It is interesting to note that the system of placing the management of water works in the hands of Councils and similar governing bodies does not find favor in the United States. It does not clearly fix the responsibility for the failure to provide for a matter of such public interest upon which the well-being and health of the community depends. Out of 225 public water works, embracing the principal cities and towns in United States in 1890–91, only 23 were so managed, the control of the remaining 202 being vested in a Board of Public Works, or a Board of Water Commissioners.

When will the City of Philadelphia awake from its long sleep? When will it throw off its lethargy and command those who are in power, and who could act if they would, to cease postponing action upon so vital a question?

PHILADELPHIA, March 16, 1896.

The Secretary read the subjoined letter, received from Dr. Leeds:

The Secretary of the Franklin Institute.

SIR:—I regret that my duties here will prevent my acceptance of your invitation to attend the meeting to-morrow evening, and take part in the discussion upon the subject of filtration, with especial reference to the present needs of Philadelphia. Inasmuch, however, as I regard those present needs as imperative, I should be sorry to let this opportunity pass without urging the corresponding need of appropriate and corresponding action.

During the years 1881, 1882 and 1883 the city expended $125,000 in an elaborate investigation of the whole subject of a future water supply. The details will be found stated at great length in the reports of the Chief Engineer for those years, and also the conclusions arrived at, which were that recourse must be had either to some distant point, like the Delaware at Point Pleasant or even as far as the Water Gap; or if this were not done, that the present sources of supply should be purified by filtration. This was thirteen years ago, and the same recommendation has been made by the head of the Water Department during each succeeding year, and reiterated by the chemists of the Board of Health, the Academy of Medicine and by the citizens' associations. As chemist of the Water Department during the progress of the survey, I advocated the plan of not abandoning our present sources of supply, but of purifying them.

My reason for so doing was that the analyses and examinations showed that the Delaware River above Point Pleasant, or above the Water Gap, and the upper waters of the Perkiomen, the Lehigh River, the Neshaminy and the Tohickon were not entirely free from contamination. Even if recourse were had to these water-sheds, there would come a time in the future when the water drawn from the best of them would have to be purified by filtration. I asked many city engineers in England why they maintained great systems of filter beds for water supplies, which, in their quality, were fully equal to that of the Delaware at Point Pleasant, or the Perkiomen above Zieglersville. They said that public opinion demanded a water supply which should at all times be free from color and sediment, and that the only practicable method of securing these ends was by filtration. The most noteworthy instance of this kind was in connection with the new supply of Liverpool. This is taken from Vyrny Lake, situated 40 miles away in the mountainous part of Wales, and filled with water so pure that it is customarily referred to by chemists as exhibiting a high grade of purity. The well-known engineer, Mr. Deacon, at that time in charge, on my expressing surprise that in case of water of this kind, he should regard it necessary to establish along the line of conduit a system of filter beds, said that he was compelled to do so by force of public opinion.

The future filtering systems of Philadelphia should, however, be installed at present in connection with the present pumping stations. The water of the Elbe, at Altona, contains rarely, if ever, less than 10,000 bacteria per cubic centimeter, usually over 20,000, and frequently 40,000 or more. This, it will be acknowledged, is densely populated sewage-holding water; yet this fact did not prevent the Altona authorities from successfully filtering the Elbe water and thus escaping the cholera epidemic which so afflicted the neighboring but unprotected city of Hamburg. What 20,000 and 40,000 bacteria per cubic centimeter means, I can best illustrate by reference to the bacteria in the Passaic

River. This river receives the sewage of Paterson, and, at a point below, is pumped directly into the reservoir and mains of Jersey City. Ordinarily, at the point of intake, it contains from 7,000 to 13,000 bacteria, and yet this unfiltered water renders Jersey City the most subject to typhoid fever of any city in New Jersey.

Granting that a system of filtration should be established, the preliminary expenditure of $250,000 to settle upon the best system for such water as is supplied from the present intakes on the Schuylkill and Delaware, would be the best way to save money in the end. It would require many pages merely to mention the questions open to discussion, in attempting beforehand to decide upon the system which Philadelphia should adopt. The relative merits of "mechanical" and "natural sand" filtration have never been tested on a proper scale by filter plants operated upon and running side by side; neither has the relative cost of removing dirt and bacteria by means of alumina, oxide or iron or similar coagulant, in comparison with slow subsidence through sand only. The proper head of water in a gravity filter; the proper depth and character of sand; the relative merits of continuous and intermittent filtration; the advantage of aeration as an adjunct, etc.—all of these points can be properly settled, not by discussion, but by actual trial. In 1883, the writer proposed the use of aeration as an adjunct to purification. It was first tried in connection with the Philadelphia water at the Corinthian Basin, and since that time, in one or another form, the aeration of the water has become a feature of water purification in many places. The city appropriated $10,000 for purchase of the aerating machinery, which might still be utilised if it has not fallen to decay in the meantime.

In conclusion, I would reiterate my often-expressed convictions that the only economically practicable way in which Philadelphia can be freed from the stigma of its present high typhoid death-rate is by putting in a system of water purification on some such lines as indicated above.

Yours, very truly, ALBERT R. LEEDS.

STEVENS INSTITUTE OF TECHNOLOGY,
HOBOKEN, March 17, 1896.

MR. L. Y. SCHERMERHORN.—During the recent freshet in the Schuylkill River, extending from February 7th, at 7.30 A.M., to February 11th, at 12 M., or during 100 hours, I made an approximate determination of the volume of water passing over the Fairmount Dam during this interval, and also the relative quantity of solid material held in suspension by the water, under the following conditions:

During the freshet the depth of water on the crest of the dam varied from 1·5 feet to 7·7 feet. The volume of water passing over the dam during the interval of 100 hours named, as calculated for the varying depths by accepted hydraulic formula, was found to be about 9,350,000,000 cubic feet. On February 9th, while the depth of water on the crest of the dam was about 2 feet, a sample of the city water was drawn from a house spigot and found to contain $\frac{1}{1200}$ part by volume of solid material.

It will be noted that the volume of solid material was determined at a time when the freshet was below its average height, and after the water had passed through the reservoir, and some sedimentation had ensued; it is therefore assumed that the determination of $\frac{1}{1200}$ part of solid material is a reasonable assumption to be applied to the entire volume of the freshet.

On such a supposition the volume of solid material carried by the freshet waters during the 100 hours named would be

$$\frac{9{,}350{,}000{,}000}{1{,}200} = 7{,}791{,}000 \text{ cubic feet,}$$

or about 290,000 cubic yards.

Assuming that the average daily quantity of water used by the city of Philadelphia is 220,000,000 gallons, or 29,300,000 cubic feet, and further, that this volume contained during the freshet the volume of solid material named, then in that event it was equal to

$$\frac{29{,}300{,}000}{1{,}200} = 24{,}400 \text{ cubic feet}$$

of solid mud contained in our water supply during one day of the freshet. An ordinary one-horse cart contains about 24 cubic feet; the above-named volume of over 24,000 cubic feet of mud would fill at least 1,000 carts, and if placed in close file would form a line nearly three miles in length; if placed on Market Street, would form a line of carts extending from its foot to Thirty-sixth Street, West Philadelphia. What would the citizens of Philadelphia think if they really saw such a procession on its way to our reservoirs with the intention to deposit such an amount of mud into our water supply for one day?

If my determinations have been reasonably correct, the Schuylkill River was, during the time named, doing what might have been done with no greater disadvantage or different results by the thousand carts loaded with mud.

MR. JOHN C. TRAUTWINE, JR., Chief of the Bureau of Water, took occasion to protest against the popular indiscriminate denunciation of members of Councils, which gives the impression that Councilmen, generally, are strangers to the taste of water, and are, therefore, indifferent to the needs of the city in this respect; whereas, even those who have been least hopeful of the passage of the pending ordinance have recognised, from the first, that there was a good working majority in favor of it, and have doubted only the possibility of obtaining the two-thirds vote necessary in cases which, like this, involve an appropriation.

He then presented a report of the results of investigations of the relative merits of sedimentation and filtration in clarifying and purifying water.

When this matter was first mentioned in Councils he shut off the smallest division of the East Park Reservoir, and proceeded to take samples from day to day, and to have them tested, bacteriologically and chemically, by Dr. A. C. Abbott, of the University of Pennsylvania. The results confirm those given by Dr. Percy Frankland in his "Micro-Organisms in Water." The first day's sedimentation left 637 out of 1,000 microbes in a given quantity of water, while the second day reduced this number to 131. From that time forward, during the remainder of the ten days through which the experiment was continued, the experiment showed but little change either way.

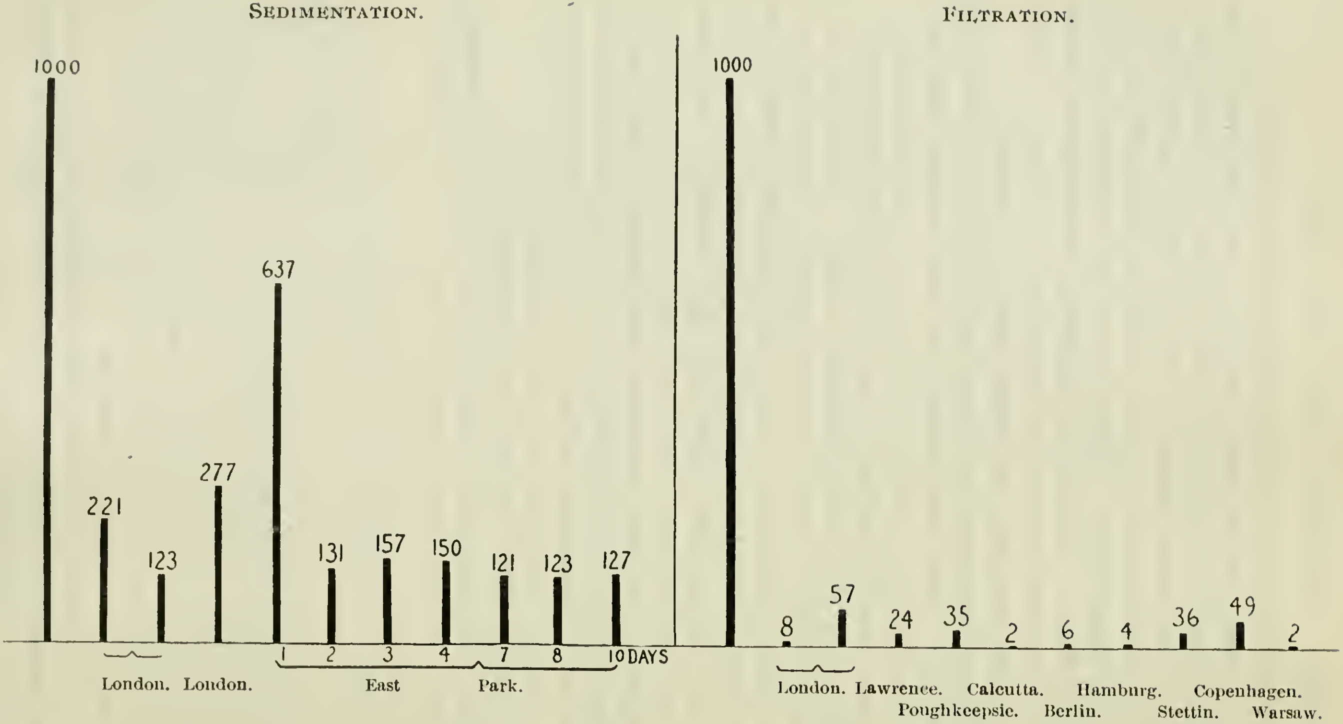


FIG. 1.—Bacteriological effects of sedimentation and filtration.

Filtration, on the contrary, effects the removal of 98, or more, per cent. of the bacteria.

These results were illustrated by means of the lantern, and samples were exhibited showing the raw water, and the effect of twelve days of sedimentation. The latter showed a slight improvement in the matter of clearness.

A sample of filtered water, taken from the tap in the City Hall, showed a rather better result, the water being clearer and whiter.

Fig. 1 shows the effects of sedimentation and of filtration in reducing the number of bacteria, the columns on the left representing the effects of sedimentation (including those obtained at East Park Reservoir, as above stated), while those on the right represent those obtained by filtration, as derived from several authorities.

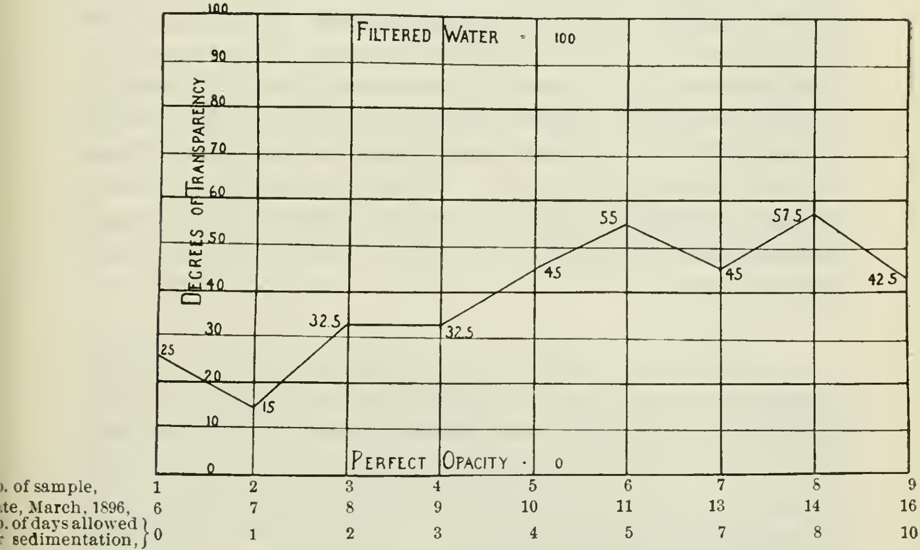


FIG. 2.—Effect of sedimentation in increasing transparency.

In each case the figures refer to a quantity (generally less than a cubic centimeter) of the raw water containing 1,000 colonies of bacteria. This quantity is represented by the line marked 1,000 at the left of each half of the diagram. On the left the next two columns, marked 221 and 123 respectively, show the results of sedimentation in a first and a second subsiding reservoir (time of subsidence not stated), as given by Percy Frankland in his "Micro-organisms in Water," while subsequent filtration reduced the number to 8, as indicated by the first column on the right.

The third column on the left, marked 277, shows the result of sedimentation in a large reservoir, where the water was allowed to settle from one to six months, and the second column on the right, marked 57, shows the effect of subsequent filtration. These figures also are taken from Percy Frankland's work.

Fig. 2 shows the mean of two sets of observations by Dr. Henry Leffmann, upon the samples from East Park Reservoir, as to the effect of sedimentation in increasing the transparency of the water by removing its visible and suspended impurities. Here perfect opacity is represented by the zero line, while the transparency of properly filtered water is represented by 100. The diagram shows that in round numbers the effect of ten days' sedimentation was to increase the transparency from 25 to 50 per cent. of that of filtered water.

Remarks on the subject were made by J. Emory Byram, Chairman of the Water Committee of the Councils of Philadelphia, Dr. Benjamin Lee, Secretary of the State Board of Health of Pennsylvania, Mr. Thomas Shaw, Dr. E. Goldschmidt, and others, the tenor of which was uniformly and strongly in favor of filtration as a remedy for the existing evils of our local water supply.

At the close of the discussion, the following resolution, offered by Mr. Shaw, and numerously seconded, was adopted without dissenting vote:

"*Resolved*, That it is the sense of this meeting that the Councils of the city of Philadelphia should make an appropriation sufficient to satisfy the requirements of the Director of Public Works for the erection of an experimental filtration plant."—W. H. W., *Secretary.*

PENDING PROBLEMS FOR WAGE-EARNERS.*

By A. E. OUTERBRIDGE, JR.

In studying the important question of management of employés of industrial establishments from a common-sense as well as just and humanitarian point of view, it is necessary to remember that a factory is not an eleemosynary institution; the functions of the two are radically different, and experience has proved that modern manufacturing industries cannot be practically conducted under the old idea of paternal or patriarchal regulations. The operative is jealous of his personal freedom and suspicious of purely philanthropic schemes originating within the establishment, and he resents any beneficial regulations savoring of charity. He does not complain of the strict enforcement of just rules, but he is quick to take advantage of laxity on the part of overseers, which, if continued, soon leads to chaos. On the other hand, unjust regulations cannot be permanently enforced under the modern labor restrictions, for labor legislation in this country is extremely comprehensive, and takes cognisance of such infractions.†

---

* An address to students of the Wharton School of Finance, University of Pennsylvania, Class in Sociology, on the occasion of a visit to the works of Wm. Sellers & Co., Incorporated, Philadelphia; with an appendix and foot-note references added thereto for this publication.

† The labor laws differ greatly in the different States. Massachusetts has led the way in such legislation, and the other States are following in her footsteps. Most of these laws increase the responsibilities of employers, thus: Methods of protection from fire and accident must be provided in all factories and workshops, and employers cannot by contract exempt themselves from liability for injuries to an employé. The buildings must be provided with proper sanitary arrangements; each room where machinery is placed must be connected with the engine room by speaking tubes, electric bells, or appliances to control the motive power.

The most minute regulations exist relating to the entire economic system of factory construction, operation and inspection; and laws governing the payment of wages, exemption from fines or garnishment of wages, or tools of trade for debts, etc., cover every phase of employment growing out of the factory system, and are distinctly favorable to labor. (See *Eng. Mag.*, September, 1895).

In some instances where labor legislation has been elaborated to a degree which was unduly oppressive to employers, it has served to restrict industrial development, reacting upon the intended beneficiary—the employé—and has necessitated the abandonment of such policy. The "granger legislation" relating to railroads in some of the Western States affords a well-known illustration of this tendency.

Employés are no longer ignorant of their rights or privileges, and employers, as a rule, neither care nor dare to trample upon them; but experience has also proved that wherever numbers of men are massed together, a certain degree of strict government is essential to the preservation of order and the proper conduct of business.

Many of the rules and regulations of workshops and factories which to the uninitiated appear harsh or unjust, are, in reality, necessary to protect the faithful employé from impositions of shirkers, of whom there is always a certain number even in the best-regulated establishments.

It is a favorite observation with writers on social and political economy that the world is continually passing through periods of "social evolution." One of the latest and most popular of these authors (Benjamin Kidd) calls the present time "the most remarkable epoch in the history of human thought." Portents of impending changes in the established order of things, affecting the very foundations of society and the welfare of mankind, are frequently revealed to the innate perceptions of such writers; and it would seem from some of these—more especially the German authors—that the industrial world is now upon the verge of a social cataclysm, out of which a new civilisation, the resultant of many opposing forces, would be evolved. Such prophecies (like Benner's) have hitherto apparently obeyed the "law of averages" with respect to the proportion of hits and misses: yet new forecasters of future social conditions, who believe that they perceive shadows of "coming events" cast before, continue to decipher these signs according to their introspective vision rather than through the light of past experience.

The fundamental principle of the Malthusian theory, that population tends to increase in geometrical progression, and that the supply of food and other necessaries of life can only be increased in arithmetical progression, tersely expressed the social problem of Malthus' generation ; but the subsequent wresting from Nature of virgin soil of vast extent in India, Russia, America, and other parts of the globe, affording feeding ground for countless flocks and herds, together with facilities for plowing, sowing and reaping unlimited crops through the aid of modern agricultural machinery, and the modern methods of rapid distribution, changed all the former conditions, rendering the law inoperative during the century which has elapsed since its promulgation. Some of the more recent prophecies have proved equally abortive, and others are likely in the near future to share the same fate.

The growth of socialism in Europe during the past quarter of a century is one of the "signs of the times" which is just now affording a fruitful field for such speculations. If we permit ourselves to view the present state of civilisation through the spectacles of some of these theorists, or if we countenance the foreign socialistic propaganda, we must, it seems to me, close our eyes to the countless evidences of truly wonderful progress in mental, moral and material welfare which has been made by the wage-earning class in America during this period. The operative of to-day is not only the peer, but the superior of his predecessor in all the qualifications that form the mental gauge by which we may measure the intellectual and social relations that an individual bears to the community in which he lives.

We may freely admit the statement of the socialist that "the rich are growing richer," but it does not follow as a corollary that the poor are growing poorer. It is true that capital, through combination, has vastly increased its power to organise and prosecute industrial pursuits on a scale of unprecedented magnitude, and that, especially as the result of energetic exploitation of new inventions, large rewards have been gained by bold investors; but I claim that, in the aggregate, labor has gained a much larger share of these benefits without incurring any of the risks.

The rich pecuniary rewards which have been reaped by Sir Henry Bessemer, and by other manufacturers who were far-seeing and courageous enough to develop his cheap process of steel-making and its later modifications, make but a small item when compared to the countless millions paid to labor during the past thirty years as the result of the development of these discoveries through the aid of capital. The Bessemer process of steel-making did more than this for labor: it sounded the death knell of the most exhausting form of toil known to man, that *inferno* of labor, the puddling of boiling iron by human hands. Many similar illustrations could be given.

I claim that modern mechanical inventions have in all cases proved to be distinctively beneficial to the wage-earner: he is, through their aid, better housed, better fed, better clothed, better educated, has more numerous and better amusements, and is thus approaching more nearly to the condition of the employer. Indeed, the wage-earner to-day enjoys many advantages of civilisation which were unknown to employers of former generations.

Herr Liebknecht, the leader of the Social Democrats in the Reichstag, presented to American readers in *The Forum* "The Programme of German Socialism." I carefully studied his paper with the view of discovering, if possible, some rational explanation of the problem—"How is socialism going to benefit the condition of the working class in America?" but the question remains unanswered. It is true that figures are given showing the marvellous growth of social democracy in the German Empire since 1890, and the author glories in the title which he gives to German social democracy, viz.: "the party of the discontented;" he also perceives signs of "an impending social crisis;" he likens the struggle between socialism and the Government to the fable of the goblin and the peasant; but the introduction of such a movement into this country could, I think, be more appropriately likened to the fable of the killing of the goose that laid the golden egg.

The recent presence in this country of more than one agitator from abroad, and the industrious dissemination of socialistic literature among our workingmen, with the evident intention of making proselytes, thereby disturbing the peace of mind of the operative, endangering the stability of our industrial laws, and tending to nullify the gain which has come to wage-earners in America through the comparative freedom from such disturbing elements, is a subject of concern to all real friends of the workingmen.

In Germany, the literature of socialism has not confined itself to agitation of labor questions, but has catered to the demand for popular reading and also for popular education. In this way it has gained the confidence of the people. "It has abused this confidence by giving distorted views of the writings of many of the greatest thinkers and educators;" it has used popular education as a club with which to beat into ignorant skulls the socialistic propaganda. The enormous socialistic vote in Germany proves the success of the force used. Such a force, if properly applied, would be immensely beneficial to humanity; but improperly used, socialism is, as Herbert Spencer declares, "the greatest calamity that has ever befallen the human race."

The most intelligible exposition of modern German socialism may be found in a little book entitled "Three Months in a Workshop," written by a student, Paul Göhre. In a prefatory note to the English translation by Prof. Richard T. Ely, it appears that "Mr. Göhre, perplexed by conflicting theories and reports touching the lot of the German wage-earners, determines to become a wage-earner himself, and, donning the garb of a workman, finds employment in a large establishment for the manufacture of machine tools in Saxony; he mingles for three months with his fellows, who never supposed him to be anything else than a wage-earner; he shares their life, participates in their amusements, attends their political meetings, and then tells what he has seen with that simplicity which is itself literary art of a high order. The narrative is plain, straightforward, truthful."

The book is more than this; it is a practical view of a subject which has been clouded in mists. The writer has shown himself a keen observer, a disinterested and enthusiastic investigator, having nerve to enter the factory on the lowest rung of the ladder, and to live and toil with the humblest employés, for the definite purpose of grasping the bottom facts of socialism as it is comprehended by the workingmen themselves, not as presented to the world by the leaders in the movement, many of whom do not really belong to the class they assume to represent. That Mr. Göhre should have succeeded, under these heroic conditions, in showing in his little book a clearer insight into the labor question and social democracy in Germany than can be found in many more elaborate treatises, is not altogether surprising. In the chapters, "Work in the Factory," and "The Material Condition of My Fellow-Workmen," the American student and operative will recognise abuses still existing in Germany, which our more progressive establishments have eliminated. The contrast, also, in rates of wages and quality of living with wage-earners in America will excite sympathy, but will also weld the American more firmly to the belief that the condition of the wage-earner in this country is a happy and fortunate one, by comparison; that its stability must not be jeopardised by countenancing socialistic agitation.*

In the chapters on "Political Tendencies of my Fellow-Workmen" and "Social Democracy," the student of industrial sociology will find much valuable information. In the chapters on "Moral Conditions" and "Education and Religion," ethical questions are plainly discussed. The final chapter, on "Results and Demands," will interest all read-

---

* On entering the shops, Mr. Göhre received 20 pfennige (4·8 cents) per hour. Compulsory deductions were made for assessments for sick benefits, insurance, fines for lateness or carelessness, etc.

Men working at the vise earned 15 to 21 marks ($3.60 to $5.04) per week; their foremen, $5.28 to $6.72; drillers, working on time, $3.60 to $4.56. "Piece workers" made considerably more. A specially skilled workman "would receive as much as 40 marks ($9.60) per week." It thus appears that the highest wage of the most skilled operative slightly exceeds the lowest wage for unskilled labor in this country. The home life of the men is shown to be on a plane far below that of the average wage-earner in America.

Some suggestive and important information is to be gathered from a book just issued by the British Board of Trade, giving the statistics of wages paid ers. It is shown that the labor question is not merely a wage question with the vast majority of the laboring class. It is only one factor in the movement—perhaps the most tangible, but not the most important or determinative one. "There is an ardent longing on the part of the whole class of factory labor for more respect and recognition, for greater actual and social equality in addition to the formal and political equality, which is theirs already. * * * It is the irresistible impulse to a larger intellectual freedom, the craving for the benefits of knowledge and education, and for a fuller understanding of those high and lofty problems of the human soul which, despite the universal pursuit of wealth and externals, rise up before humanity to-day, new riddles in new forms. All this, rough, discordant, full of anomalies and extravagances, yet plainly visible to the observant eye, stamps the beginning of the labor movement in Germany."

If confined to such lofty aims, the mission of socialism would be worthy of, and would command the sympathy and hearty co-operation of all enlightened people ; but Mr. Göhre shows that it is necessary first to unmask the hypocrisy of social-democratic literature, to oppose the true to the false, the impartial to the partisan ; he tells us that "German Social Democracy is to-day not merely a political party, not merely the promoter of a new system of economics, or even both of of these and nothing more ; it is also the embodiment of a philosophy, a logical, anti-Christian, materialistic conception of the universe. Upon this materialistic system it founds its

---

for manual labor in Great Britain. From this it seems that the average earned by men is $6.03 a week; by women, $3.08; by boys, $2.24; and by girls, $1.56. These are the averages of the wages of 816,106 persons. In Scotland, the rates are lower than in England by 10, and in Ireland by some 20 per cent. The best-paid trade is that of builders, and then, in order, distillers, brewers, metal workers, engineers, saw-mill workers, coach builders and printers. Railroad men average $5 a week. The chances of earning $10 a week are not common; 37 per cent. of the printers, 33 per cent. of the tinplate workers, 13 per cent. of the ship-builders, 11 per cent. of copper and brass workers and 10 per cent. of coopers attain that amount. On the whole, the report indicates that wages in all British trades are on the increase, but at a very slow rate of progress.

economic and political system. This principle, the caricature of a so-called science, worshipped by its followers, is the corner-stone of the party, gives it authority and ideals, and exercises the most fatal and lasting influence, not so much on the social and political tendencies as on the intellectual and ethical character of the whole German laboring class." This new gospel of socialism ran like wildfire among the hundreds of thousands of German workingmen. Herr Liebknecht tells us that "nearly 2,000,000 of men voted for the socialistic programme on the 15th of June, 1893, to whom must be added nearly 1,000,000 of voteless young men between the ages of twenty and twenty-five years."

The spread of socialism in Germany has now reached the degree which is popularly termed with us a "craze." Its earliest converts became its new prophets, its inspired preachers; from inner conviction they gave their whole strength, their utmost capacity, to the cause. "Wherever two or three met together, men set forth and discussed the thoughts they had imbibed from one book or half a dozen books of the new literature; sometimes fairly grasped, sometimes only half comprehended and more than half forgotten, but always brought afresh to their minds by the articles in their social-democratic paper. * * * The effect of this agitation was the one desired. Under its pressure all the old youthful training of the workman gave way, and is still giving way in every individual who brings such training with him to a factory where the spirit of social democracy prevails."

If, now, we cull out these true and noble yearnings of the workingmen, discarding the sophistries of their self-elected leaders, we find that their aims are those which have already been largely attained by the wage-earning class in America through education; and while we may reasonably sympathise with the German "party of the discontented," we have nothing to gain by the dissemination of their socialistic literature, though they have much to learn from us.

In England the socialistic movement presents a different phase of development; there are fewer factions or cliques of socialists, and the tendency toward anarchism, while not so rabid as among the most radical wing of the party in Germany, is apparently even more generally diffused. Some of the recent socialistic literature published in England has a decided flavor of anarchism, at least in so far as it preaches the overthrow of laws by which land is held in private ownership; the private or corporate ownership of all kinds of property, factories, railroads, telegraphs, etc.; and evidences are not lacking of widespread discontent and unrest among the industrial population, which devours such literature with avidity. It is reported that 1,000,000 copies of a single book of this character have recently been sold to workingmen in England.

The latest cabled reports indicate that a reaction in labor sentiment has set in in England. There was recently in session at Newcastle a "Free Labor Congress." The president's opening address is reported to have been "a vigorous attack on trades-unions, which, he declared, were manipulated by self-seekers, whose tyranny disgraced the cause of labor." His association, he said, had already formed "boards of conciliation" at many important centers. These boards were formed of equal numbers of masters and operatives, and were all working in perfect harmony. An editorial writer, commenting upon this cablegram, says: "The revolt from trades-unions was not unexpected. It was bound to come as soon as the more intelligent workmen perceived that they could no longer own themselves, but were virtually made slaves of the lazy and inefficient members of the organisation. It is singular that this should have been perceived first in England instead of in America." This writer is evidently not well informed in the history of the rise and fall of several labor-unions in this country, which, a few years ago counted their members by thousands, where they now number units. Compared with a period of four or five years ago, the larger number of the unions have sunk into a condition of "innocuous desuetude," controlled by cranks.

Labor-unions, however, should not all be classed under one category, for some of these are beneficial organisations, with high motives, sound constitutions, and, above all, wise leaders. Such organisations are opposed to violence and disorder, encourage harmony and arbitration, and are mutually beneficial and helpful to employer and employé; they are aiding to discourage the spread of anarchism and socialism in this country.

Socialistic theories are inimical to American ideas and principles, for the humblest workman is a free citizen, to whom a pathway is opened to the highest positions of honor and wealth. Many of our foremost men have risen from lowest origin, and have no cause to be ashamed thereof. Socialism can offer no commensurate advantages; its tendency is not to raise the masses to a higher plane, but to reduce the competent to the level of the incompetent. The world is always crowded with incompetent operatives, while at the same time there is an unsatisfied demand for the absolutely competent.

In daily friendly intercourse with workingmen, extending over a period of twenty years, I have found a prevalent idea in many minds that employers of labor are, as a class, jealous of the material advancement of wage-earners beyond a certain point; that a maximum wage is soon reached beyond which they cannot hope to pass, and that extra effort on their part would result merely in an increase of tasks without a corresponding increase of pay. This impression is more generally inculcated in the minds of operatives than employers realise, and it operates to their mutual disadvantage. Modern "piece-work" systems of pay have been devised (and are now generally practised) with a view of stimulating workmen to produce the greatest output and largest percentage of perfect work; but these elaborate systems are, to a certain extent, rendered inoperative by reason of the suspicion mentioned. That there may have been, and may still be, some ground for such impressions I do not dispute, but I do believe that a more enlightened view of the mutual relations existing between employer and employé is gradually permeating the industrial world.

The great development of mechanical invention has not only increased the demand for skilled labor by increasing the output and opening constantly new fields of labor, but it has increased tenfold, and in some instances one hundredfold, the possible product of labor *per capita*. This is the reason why the American employer, paying the highest wages in the world, is, nevertheless, able to compete in the markets of Europe with so-called "pauper labor" in many manufactured articles.*

It has been proved by actual experiment on a large scale in certain sections of this country, that ignorant foreign pauper labor in manufacturing industries is ultimately the most costly, and the aim of enlightened employers today is not to obtain the cheapest labor but the most intelligent service. The true policy of the workingman is, therefore, not agitation but education.†

---

* Mr. Mulhall, the English statistician, has recently published some tables relating to the producing power of the different nations of the earth. They show an enormous increase during the latter half of the century of the productive power of the people of this country, and they prove, moreover, that no other nations possess equal producing power *per capita*. By the figures which he has tabulated, Mr. Mulhall shows that from 1820 to 1890 the "foot-ton" power of the United States increased from 4,292,000,000 foot-tons daily to 129,306,000,000 foot-tons. A foot-ton is a method that statisticians have of measuring the producing powers of a country. It signifies the ability of a man to accomplish, with ordinary exertion in ten hours, an amount of work equal to raising 300 tons 1 foot high. In 1820, the forces at the command of the Americans were equal to 446 foot-tons of power *per capita* of the population. By 1890, the productive forces had increased to 1,940 foot-tons *per capita*. These forces are now busily engaged in developing the resources of the country, in cultivating the soil, working the mines, operating the industries, carrying on the commerce, or in looking after the development of the mental powers and the enlightenment of the people, whereby their producing powers may be still further increased.

Next to America in the scale comes Great Britain, the producing power of which is 1,470 foot-tons to the inhabitant daily. Germany's forces amount to 902 foot-tons for each person daily; those of France to 910 foot-tons; those of Spain to 590 foot-tons; those of Austria to 560 foot-tons, and those of Italy to 380 foot-tons.

† Thomas Carlyle, in his essay on Labor, said: "The latest gospel in the world is, Know thy work and do it; * * * for labor is life; from the inmost heart of the worker rises this God-given force. * * * Knowledge, that will hold good in working, cleave thou to that, for Nature herself accredits that, says 'Yea' to that. Properly thou hast no other knowledge but what thou hast got by working; the rest is all a hypothesis of knowledge —a thing to be argued of in schools, a thing floating in the clouds, in endless logic vortices, 'till we try it and fix it.'"

The organisation through the aid of capital of large industrial operations, superseding former small independent industries, is a frequent source of lamentation on the part of well-meaning philanthropists and others, on the theory that the small merchant has been injured thereby. This is probably true in isolated instances, but the evidence that the wage-earner (the subject of our discussion) has been benefited by improved regulations, superior factory buildings, and amelioration of exhausting toil under modern methods, is overwhelming.

Moreover, the employment of large capital and improved machinery has enormously increased production and decreased cost to the consumer. Wages are higher and cost of living is lower than formerly. The average wage-earner in America lives to-day in a manner quite superior to the small manufacturer of former days. The large factories employ armies of skilled operatives, many of whom would be incompetent to conduct even small industries successfully. They are reasonably assured of a fixed income, and are often enabled, by saving a portion of their wages, to become small capitalists themselves. Capital is, after all, nothing more than the aggregate savings of labor. The great financial operations are conducted by the aid of these savings of the masses, otherwise the thrifty workingman could receive no interest on his deposit in the savings' bank. The individual millionaire is a much less important factor in the world's work than the socialistic agitator would have us believe.

The "good old times" are hallowed in our recollections and in our traditions; but when subjected to critical comparison with the improved civilisation of modern times, we find, I think, that the masses have gained immeasurably in all the comforts and conveniences of life, in social position, in political power, in freedom from care, in health and happiness.

The coming conflict between proletariat and plutocrat is a favorite theme with socialistic writers. According to these, wealth is *per se* criminal, and its chief employment the oppression of the poor. I claim that modern experience proves the antithesis of this statement, which selects exceptional instances of financial crimes and attempts to use these as a blanket with which to smother all the good deeds and grand undertakings in which capital is ever engaging. Patriotic sentiment also protests against such statements. The aid of capital has been the means, within little more than a century, of raising the United States of America from the condition of an insignificant agricultural colony, which was not permitted under monarchical rule to manufacture the simplest articles for home consumption, into the greatest workshop of the world, and has placed it in the front rank of wealth and power among nations.*

Capital has stimulated the inventive faculty of the people and thereby aided the operative, in many instances, to emerge from the condition of the laborer into that of the capitalist. Very many, perhaps a majority of employers in this country, are men who have risen from the ranks of labor.

The reckless denunciation of wealth by foreign socialistic agitators is the chief danger confronting the industrial class in America to-day, since it tends to retard investment of capital in industrial enterprises, and thus to restrict the employment of labor. It is far easier for the agitator to "kill the goose that lays the golden egg" than it is for the mischief-maker to turn his hand to honest labor. The free soil of America is not adapted to the growth of such noxious weeds, and the sooner such pernicious doctrines are eradicated, the sooner will our industrial population reap the rewards to be gained in the returning prosperity for which it has so long and patiently waited.

---

*The first spinning jenny ever seen in America was secretly imported from England and exhibited in Philadelphia in 1775. In 1774, the British Parliament enacted stringent laws prohibiting the exportation to America of textile machinery. It was provided (by 21 George III, Chap. 37) that "any person who packed or put on board, or caused to be brought to any place in order to be put on any vessel for exportation, any machine, engine, tool, press, paper, utensil, or silk manufacture of the kingdom, or goods wherein wool, cotton, linen or silk are used, or any model or plan of such machinery, tool, engine, press, utensil or implement, should forfeit every such machine, etc., and all goods packed therewith, and £200, and suffer imprisonment for one year." In 1782, a law was enacted which prohibited, under penalty of £500, the exportation or attempt to export "blocks, plates, engines, tools or utensils used in, or which are proper for, the preparing or finishing of calico, muslin, etc." The same act prohibited transportation of tools employed in iron and steel manufactures.—U. S. Tenth Census, Vol. II, p. 537.

APPENDIX.

The Cost and Danger of Strikes.—Few persons are aware of the enormous annual loss of wages due to strikes. Startling figures are furnished by the Labor Bureau at Washington in a recent publication, covering the period from 1881 to 1894, inclusive.

It appears that no less than 3,714,406 persons were thrown out of employment, suffering a loss in wages of $163,807,866. Fifty-five and one-half per cent. of the strikes failed entirely; 32 per cent. are classed as successful, and 12½ per cent. as doubtful, or partly successful. Labor organisations contributed $10,914,406 to assist strikers.

The promoters of strikes argue to their comrades that unsuccessful efforts are, nevertheless, ultimately beneficial; but study of the subject has led me to take the opposite view, viz.: that all strikes of skilled workmen are, in the end, harmful to the participants. No one single cause has done more, in my opinion, to hasten the introduction of entirely automatic machinery in operations where a certain degree of skilled labor was considered indispensable, than strikes on the part of such skilled employés. Numerous instances might be recalled where large manufacturers have, on account of strikes, cheerfully expended immense sums of money in perfecting automatic machinery, not primarily to effect economy in wages, but as an insurance against future danger from such causes.

A notable instance of this nature occurred a few years ago at one of the largest iron and steel works in the world. In a certain department, specially skilled men were able to make wages which now seem incredible; they were, however, paid a percentage upon the tonnage, and, owing to enormous output, the profits of these operatives exceeded in some years that of many successful manufacturers having large capital at stake. These men considered themselves indispensable, and struck—not for higher wages or shorter hours—but at the dictation of outsiders. When work was resumed, they found their occupation gone forever; automatic machinery had supplanted the former skilled labor.

I do not believe that any employé (I myself am one) is indispensable, and many highly skilled and otherwise valuable operatives have, unfortunately for themselves, failed to appreciate this fact until too late.

The danger I have indicated regarding the effect upon skilled labor of strikes, does not appear to have presented itself to the minds of the workingmen; and if their leaders have perceived it, they have concealed it. I regard the strike as a barbaric weapon of attack, resembling somewhat the boomerang, which, we are told, frequently returns and injures its projector.

Another element of danger to the workingman, which usually accompanies a strike, is the license which it affords to the irresponsible and lawless element of society to commit depredations, endangering the lives and property of innocent persons, and sometimes compelling the use of armed force for its suppression. The strikers, though innocent of these overt acts, are injured thereby, and the suspicion lurking in many minds is not without foundation, that some leaders of strikes, while openly exhorting their followers to preserve the peace, secretly count upon this outside aid; and, if they do not, they are strangely blind to the result of past experience.

The Eight-Hour Agitation.—This is the fundamental principle or philosophy of the trades-union movement in this country, and, in 1888, the American Federation of Labor, numerically one of the strongest of the unions, voted to unite with the Eight-Hour League, and thenceforth to concentrate all effort on the struggle for eight hours. Their program was then to take charge of one trade at a time. Thus, in 1890, the gauge of battle fell to the lot of the carpenters, who accordingly struck, under orders, for an eight-hour day on May 1st, and won temporary victories in 137 cities. Plans were laid for the miners to strike on May 1, 1891, for eight hours, but the conditions were not then favorable; and, although these plans have since been in abeyance, owing to depressed conditions of trade, they have not been abandoned, and I have reason to believe that employers in almost all trades will be called upon to meet this question in the not very distant future.

The argument of the eight-hour philosophers is that, by restricting the hours of work, more laborers must be employed and the idle surplus provided for. I consider that this is specious reasoning. The overflowing stream of immigration from European countries, attracted to America by comparatively high wages, suffices even now to produce a permanent flood, at least in the fields of unskilled labor. If to this we add the still more powerful attraction of a legal working day of eight hours, the tidal wave flowing from all the less-favored countries in the world would swamp our native industrial population, and induce a condition which would be far less favorable to them than that which now obtains.*

---

* I am able to substantiate these views by figures bearing upon the subject. The official statistician of Paris, M. Bertillon, gives the proportion of foreigners in that city as 7·5 per cent.; these are chiefly wealthy persons who distribute a portion of their funds among the tradespeople. London and Vienna have each 2·2 per cent. Berlin has 1·1 per cent. of foreigners, also mainly persons of wealth.

The foreigners residing in American cities are chiefly poor immigrants, who compete with the native working class for wages, and are accustomed and content to live in comparative squalor. The percentages of "foreign-born" to total population in five principal American cities are as follows: Philadelphia, 25·74 per cent.; Boston, 35·27 per cent.; New York, 42·23 per cent.; Chicago, 40·98 per cent.; Milwaukee, 38·92 per cent. More than 30 per cent. of the foreign-born males, 21 years of age and over, in the five cities named, are aliens. The percentages of "persons of foreign parentage" to total population in these cities are as follows: Philadelphia, 56·58 per cent.; Boston, 67·96 per cent.; Chicago, 77·90 per cent.; New York, 80·46 per cent.; Milwaukee, 86·36 per cent. This information was courteously furnished by the Chief of the Census Division, Department of the Interior, Washington, March 12, 1896.

More rigid enforcement of contract labor laws has decreased importation of foreign labor under direct or written contract, but there is ample evidence that Italian labor purveyors still influence such immigration. Immigrant Inspectors Birmingham and Hinkle reported (under date of January 11, 1895) to the Secretary of the Immigration Investigation Committee, among other

The eight-hour party has succeeded, through political influence, in making eight hours a legal working day in governmental employment, and largely also in municipal contracts, and violators of the law have been rigorously prosecuted. A remarkable case occurred in Buffalo, which worked great hardship upon a citizen, and led to the decision of Justice White, of the Superior Court at Buffalo, declaring the eight-hour law unconstitutional. Justice White's decision was based upon the clause of the Constitution which provides that "no person shall be deprived of life, liberty or property without due process of law." That provision of the Constitution has been construed to mean that the rights and privileges of a citizen to make contracts relating to his business or property cannot be interfered with by legislation. It has

---

facts, as follows: "Mr. Desabadia (an Italian padrone of New York) informed us that he was regularly engaged in supplying Italian laborers, in any numbers, to contractors or others desiring labor done; that he was prepared now to furnish from 200 to 600 men (Italians) for work of any nature; that he could furnish stone-masons, carpenters or men of almost any of the building operations."

The equivalent of the padrone system is not confined to Italians. Poles, Hungarians, Greeks, and other foreigners, temporarily camping in this country, are forwarded, "on call," wherever large operations are in progress, crowding out American labor by accepting lower wages. In Texas and other border States, invasions of Mexicans occur at regular intervals, especially at sheep-shearing time; these people contribute nothing to the wealth of the country, and patronise the railways by walking home on the ties!

An investigation made by the Senate Committee on Immigration in 1893 (Senator Hill, chairman) developed the startling fact that Italian bankers remitted to Italy from New York City alone $25,000,000 to $30,000,000 a year, largely savings of "Dago" laborers, and a marked increase in wealth in certain sections of Italy has been traced directly to money earned in the United States by these "birds of passage." Italians who have become domiciled here for a few years are beginning to make incursions into skilled labor fields where formerly they were unknown, and where even a suggestion of the kind would have been ridiculed. In the shoe trade, for example, it is said that large numbers of Italians have been substituted for American workmen who went out on strike some time ago.

The facts stated in these various foot notes have been gathered by the writer at different times during several years from a variety of independent sources, and it is only when placed in juxtaposition that their true significance becomes apparent. These illustrations are but a few samples of facts at hand that are too numerous to mention, and they present practical problems for legislators and workers, of far more importance than any theoretical discussions.

been declared by the courts that liberty, in its broad sense, as understood in this country, means the right not only of freedom from actual imprisonment, but the right of one to use his faculties in all lawful ways, to live and work where he will, to earn his livelihood in any lawful calling, and to pursue any lawful trade or vocation. All laws, therefore, which impair or trammel these rights, which limit one in his choice of a trade or profession, or confine him to work or live in a specified locality, or exclude him from his own house, or restrain his otherwise lawful movements, except where the public health or safety intervenes, are infringements upon his fundamental rights of liberty, which are under constitutional protection.*—People *vs.* Warren, 34 N. Y. Supp., Superior Court, Buffalo, 942.

The impossibility of regulating the rate and hours of labor by legislation, unless in the exercise of the police power, or law of public health and safety, was recognised years ago by Chief Justice Ruger, in McCarthy *vs.* Mayor,

---

*"Henry J. Warren, superintendent of the Barber Asphalt Company, was convicted by a police court in Buffalo of a misdemeanor for a violation of this (eight-hour) section of the Buffalo charter, and punished by imprisonment. From his conviction he appealed to the Court of Sessions and to the General Term of the Supreme Court, where the conviction was affirmed, the courts holding the act constitutional and the conviction valid. As Warren could not by law appeal to the Court of Appeals in that case, he sued out a writ of *habeas corpus* in the Supreme Court, to test the questions affecting the validity of the conviction, and to inquire by what authority he was restrained of his liberty. This proceeding is a good illustration of the efficacy of the ancient writ of *habeas corpus*, for, although the Special and General Terms of the Supreme Court dismissed the writ, and again declared the prohibitory statute constitutional and the accused properly convicted, yet, upon an appeal to the Court of Appeals, the decisions of the lower courts were reversed, and the arrest, trial and conviction declared without jurisdiction and void.

"After this long and tedious fight Warren was released, only to be arrested again for a violation of the eight-hour law, this time for employing an alien Italian laborer. He was indicted by the grand jury, and convicted in the Superior Court at Buffalo. His counsel contended that the act in question, so far as it seemed to prohibit the employment of alien laborers upon public works, was repugnant to the Federal and State Constitutions and to the treaty between the United States and Italy. Upon an appeal to the General Term of the Superior Court, the act, so far as relates to the employment of aliens, was declared unconstitutional, and Warren was discharged."—People *vs.* Warren, 77 Hun., 120; People *ex rel.*, Warren *vs.* Sheriff, 144 N. Y., 225.

who said in reference to the original eight-hour law then under discussion:

"It is well to premise that this act was not intended to affect or regulate the rate of wages which should govern as between employer and employé. That subject is left by the act, as it always must remain, open, to be fixed by the agreement of the parties intending to enter into those relations. Experience has shown that legislation on the subject must always be futile and ineffectual, for the reason that it is controlled by the natural laws determining the value of labor and property, and which are as much beyond the power of statutes to affect as they are above the control of the wishes of the parties interested therein."

I do not mean to imply from the foregoing statements that I am opposed to shorter hours for labor; on the contrary, I believe that a shorter working day, wherever it is practicable, is beneficial alike to employé and employer; but under present conditions, it appears to me, after a careful survey of the field, that there are some prominent obstructions which must be removed before an eight-hour day can be universally adopted, or before the operatives who now work ten hours a day can reasonably hope for a general reduction to eight hours without a corresponding reduction of wages.

Wise men usually count the cost of any new undertaking before embarking in it, and a very simple calculation will show surprising figures as to the additional cost of manufacture should employers be called upon to pay the same wage for eight hours' that they now pay for ten hours' work. If we assume that an establishment employs a thousand hands (there are factories having capacity for four or five times this number), a reduction of two hours per day per man would mean an aggregate of two thousand hours' reduction per day in the shop. Assuming the average wage to be 10 cents an hour (this is much below the true average), the additional cost for this item alone would be $200 per day; while the loss from decreased output and increased fixed charges, rate of interest on plant, etc., per unit of product, would, I believe, extinguish any margin of profit obtained under present prices in any manufactured article where competition is keen. It is, of course, possible that in those occupations in which the output depends more upon manual dexterity than upon the mere tending of automatic machinery a decrease of working hours may be partly offset by an increase of effort; but this would, I think, prove an exception, the effect of which is, in part at least, discounted by the low figure selected to represent average wages.

It is apparent that a rearrangement of some kind would be necessary; is it not likely that this rearrangement would be found in a corresponding reduction of wages?

Sympathising as I do with all legitimate efforts of workingmen to better their condition, it appears to me that the aim of their organisations should be to secure a reduction in the hours of those workers who are now compelled to submit to clearly excessive consecutive hours of attention to duty—conditions that are not only deleterious to the welfare and happiness of the laborer himself, but in some instances increasing the danger to life and limb of others, whose interest and sympathy would be a powerful lever, if properly applied, to help to remove this incubus resting at present upon the boasted freedom of labor in this country.

If the views which I have here advanced shall have the effect of tending, on the one hand, to discourage the unwise and impracticable schemes of some misguided wage-workers, and, on the other hand, to stimulate keener and more general interest on the part of employers of labor in the welfare of their operatives, and thus to foster a closer union between these two great interdependent elements of society, I shall feel that my efforts have been repaid. The nature of my occupation for the past fifteen years has perhaps afforded unusually favorable opportunities for viewing both sides of the sociological questions here discussed; it has certainly aroused keen personal interest in the subject and has stimulated study of these problems.

THE ELECTRO-METALLURGY OF ALUMINIUM.*

By Dr. Joseph W. Richards, A.C., Lecturer on Electro-Metallurgy at the Lehigh University.

Metallurgy is the art of extracting metals from their ores, and of refining them to the purity required for their use in the metal industries.

Electro-metallurgy is that branch or division of the metallurgic art which concerns the use of electricity as an adjunct to, or a substitute for, the ordinary methods of extracting metals from their ores or refining crude metal. Electrical methods may enter into metallurgical operations in three stages, viz.:

(A) Electrical refining of crude metal which has been produced from the ore by non-electric methods.

(B) Electrical reduction or production of crude metal from the ore, which is afterwards refined by non-electric methods.

(C) Electrical reduction and refining, or the entire substitution of electric for non-electric methods. The operations of reduction and refining may take place together, in one operation, or be effected consecutively, independently of each other.

The electrical methods used in metallurgy may be classed, as to their character, under three heads, viz.:

I. Electrolysis of aqueous solutions.
II. Electrolysis of fused electrolytes.
III. Electric smelting, or electro-thermal operations.

Considering these operations in order, I will enumerate the kind of metallurgical operation for which each is capable of being used.

I. Electrolysis of aqueous solutions may be used for:

(1) Refining crude metal, using it as soluble anodes in the solution of a salt of the same metal.

---

* A lecture delivered before the Franklin Institute, January 24, 1896.

(2) Extracting metals *directly* from their ores by using the ores themselves in the form of soluble anodes, in the solution of a salt of the same metal.

(3) Extracting metals *indirectly* from their ores by

a. Producing from the ore by some other means, chemical or electrical, a compound which can be used as a soluble anode, as in the former division. This method is especially applicable when the ore itself is unfit for use as a soluble anode.

b. Treating the ore chemically so as to convert it into a soluble salt; dissolving this in water, and precipitating the metal by electrolysis, using either insoluble anodes, or soluble anodes of a cheaper metal placed within porous cells.

II. Electrolysis of fused compounds may be applied to:

(1) Refining crude metal, using a fused salt of the same metal. This method is of very limited application.

(2) Extracting metals *directly* from their ores. This is applicable only when the ore itself is an easily fusible compound, in which case it is melted and electrolysed, using either an insoluble anode, or one which will combine with the non-metallic ingredient of the ore and form an inert compound.

(3) Extracting metals *indirectly* from their ores by:

a. Converting the ore into some suitable fusible compound, and then electrolysing this, as above.

b. Dissolving the ore in some fused salt which acts as a solvent for the ore, and which requires a higher electromotive force to decompose it, in which case a current of properly regulated potential will decompose the ore without affecting the fused salt which acts as its solvent. Either soluble or insoluble anodes may be used, as in (2).

III. Electric smelting or electro-thermal methods are those in which the apparatus is arranged so as to convert the electric energy as largely as possible into heat, the heat thus developed being utilised to effect chemical reactions or reductions. The ore, in contact with the substance or substances necessary to reduce it, is so placed in the apparatus as to be subjected to the electrical heating, and is thereby reduced. Frequently the carbon used in the apparatus to convey the electric current serves as the reducing agent, as in reducing ores containing oxygen.

Electric smelting may be applied to:

(1) Extracting metals in a crude state *directly* from their ores.

(2) Extracting metals in a pure state from the purified ore, or from a pure compound of the metal prepared from the ore.

It is sometimes difficult to draw the line precisely between Classes II and III, because of the fact that, during the electrolysis of a fused salt, there is necessarily developed by the electric current an amount of heat proportioned to the conduction-resistance of the fused salt; and when the amount of current used for electrolysis is very large in relation to the size of the bath, the development of resistance heat may become so large as to keep the bath fused without the application of heat from an external source, and the process would then seem to have passed into the class of electric smelting processes. Such, however, I should not consider to be the case, because the electric heating, rendering the apparatus independent of external heating, is, in this case, only an incident to the process; the principle of the method does not depend on it at all. The electrical decomposition of fused salts is, therefore, to be distinguished by the low resistance of the bath, the low potential required to operate it, and the presence of those arrangements necessary for economical electrolysis. The temperatures attained in electric smelting furnaces are generally very high, reaching to nearly 4,000° C. (7,000° F.), and under such conditions chemical reactions are effected which are impossible in any other form of furnace.

With this introduction, let us consider

THE ELECTRO-METALLURGY OF ALUMINIUM.

The native minerals which may be considered as the available ores of aluminium are as follows:

Bauxite.—Impure hydrated oxide of aluminium, carrying usually some ferric oxide, silica and titanic oxide. It is insoluble in water, easily soluble in strong acids after being calcined; infusible, except in the electric furnace, and then practically a non-conductor of electricity. Soluble in certain fused fluoride salts, particularly the double fluorides of aluminium and the alkali metals. The resulting bath is a good electrolyte.

Cryolite.—Double fluoride of aluminium and sodium, usually impregnated with some silica. Insoluble in water, easily fusible at a bright-red heat, and then a good conductor of electricity, which liberates aluminium and fluorine (very irritating fumes).

Native Alums.—Included under this general head are the native sulphate of aluminium, or double sulphates of aluminium and the alkalies. Soluble in water; the acid of the aluminium sulphate driven off by gentle heating, leaving either an infusible residue of alumina or a pasty mixture of alumina and alkaline sulphate, from which the latter can be removed by washing.

Kaolin.—The pure, white china clay. A hydrated silicate of aluminium. Is found in immense quantity and very pure. Insoluble in water, infusible, except in the electric furnace; unattacked by acids, except sulphuric acid, which dissolves out the alumina and leaves the silica; and by hydrofluoric acid, which removes the silica and leaves aluminium fluoride.

The chemical compounds of aluminium which may be considered available for use in electric processes, and which may be formed by chemical processes from the ores and then used as the intermediate products mentioned in our classification, are briefly as follows:

Aluminium Chloride.—Formed by an expensive operation from alumina. Attracts moisture strongly from the air, easily soluble in water (the aqueous solution may be made by dissolving alumina in acids). Fusible easily, but fumes in the air and volatilises at a temperature close to that of its melting point. The fused salt conducts electricity very poorly.

Aluminium Chloride with Alkaline Chloride.—Formed in the same manner as the simple chloride, alkaline chloride being added in the process. Easily soluble in water, only slightly deliquescent, easily fusible, and the fused salt a good electrolyte. Much easier to work with and handle than the simple chloride.

Aluminium Fluoride.—Can be made cheaply from the ores. Nearly insoluble in water, infusible, volatilises at a high temperature, soluble in many fused salts, and the resulting bath a good electrolyte.

Aluminium Fluoride with Alkaline or Alkaline-Earth Fluorides.—Insoluble in water, easily fusible salts, good conductors of electricity, dissolve alumina freely, and allow of *its* electrolysis without being themselves decomposed.

Alkaline Aluminates.—Soluble compounds of alumina and potassa or soda. Fusible with difficulty and decomposed by the current into alkali metal, aluminium and oxygen. Electrolysis unsatisfactory. Made by heating together alumina and the alkali; or, in solution, by dissolving alumina in solution of caustic alkali.

Metallic Aluminates.—Difficultly fusible compounds, troublesome to make and mostly insoluble in water; scarcely available in any electric method, excepting, possibly, in the electric furnace.

Aluminium Phosphate.—Insoluble in water, nearly infusible and very difficult to decompose.

Aluminium Borate.—Difficultly soluble in water, easily fusible, and when fused, a good electrolyte. Made by dissolving alumina in boric acid or borax. The current, however, liberates boron also.

Aluminium Nitrate and Acetate.—Soluble salts formed by dissolving alumina in the corresponding acids. Decomposed by gentle heating, leaving alumina.

Aluminium Sulphide.—A difficultly-fusible compound; attracts moisture, reacts on water, setting free hydrogen sulphide and leaving alumina. Made only with difficulty, by passing carbon bisulphide vapor over red-hot alumina. Hardly suitable for any electrical process.

Aluminium Sulphide with Alkaline Sulphides.—Easily fusible salts, made with comparative ease by melting together alumina, carbon, sulphur and an alkali. Stable in the air, insoluble in water, and when fused, good conductors and easily decomposed by the current into aluminium and sulphur.

Before taking up in detail the different kinds of electric processes, allow me to make a few remarks on the properties of aluminium itself.

Aluminium melts at 625° C.—a dull-red heat. It volatilises slowly at the temperature of the electric furnace. In mass, it is very slightly affected by air or water, but when finely divided, burns rapidly in air and oxidises rapidly in water. Easily soluble in solutions of caustic alkalies and in hydrochloric acid; very slowly attacked by sulphuric, nitric or hydrofluoric acid. Conductivity for heat and electricity about one-half that of silver. Specific gravity, 2·7; when melted, 2·5, causing some difficulty in working fused baths. Rapidly attacked by melted silicates, borates or any salts which it can decompose. Its atomic weight is 27, its chemical equivalent 9. Its electro-chemical equivalent, therefore, is 0·00009315; that is, an electric current of 1 ampère will set free by electrolysis, from any aluminium compound capable of electrolysis, 0·00009315 grams of aluminium per second, or slightly over one-third gram per hour, or 8 grams (= $\frac{1}{4}$ ounce) per twenty-four hours.

The minimum voltage necessary to decompose the aluminium compounds, whose heats of formation are known, is as follows:

	Volts.
Aluminium fluoride	4·0
" oxide	2·8
" chloride	2·3
" bromide	1·7
" iodide	1·0
" sulphide	0·9

We will now proceed to consider the electric processes according to the preceding classification.

I. Electrolysis of Aqueous Solutions.

(1) Refining of crude metal.

The question of thus refining impure aluminium to a high standard of purity is one to which very little attention has thus far been given. Since the solution of metal at the anode balances the deposition of metal at the cathode, no voltage is absorbed in electric decomposition; potential is needed only to overcome the conduction-resistance of the electrolyte, and the water need not, therefore, be decomposed. The difficulty is to deposit the molecules of aluminium upon the cathode more rapidly than such finely divided particles can be oxidised by the water, otherwise the deposit is entirely changed to alumina. This difficulty is met by using a current of large quantity per unit of depositing surface. I give below the results of an experiment made by myself several years ago:

Solution.—A strong solution of aluminium chloride *plus* 10 per cent. of sodium acetate.

Voltage.—0·9 volts across the electrodes.

Resistance.—Of battery and wires . . . . 0·7 ohms.
Of solution . . . . 1·55 "
Specific resistance of the solution . . . . 20· "

Current.—0·4 ampères, giving a current density of 290 ampères per square meter of cathode.

Results.—A liberal evolution of gas at the cathode, apparent attack of the anode (impure aluminium) and, in fifteen minutes, a bright metallic deposit of aluminium on the cathode.

I have quoted this experiment simply to prove the possibility of thus refining impure aluminium, and it is within the range of possibility that at some future time we may see impure aluminium being refined on these lines, just as copper is now treated.

To a Philadelphia audience the chief interest in this part of my subject will probably be concerned with the aluminium plating on the tower of the Public Buildings. This plating is deposited from aqueous solution, using soluble aluminium electrodes, but it is important to state that the bath used contains a tin salt as well as an aluminium salt. The deposit is, therefore, a mixture, or possibly an alloy, of aluminium and tin, which is much easier to deposit than pure aluminium, as the tin protects the particles of aluminium from oxidation during deposition. This method of procedure, therefore, is not applicable to the metallurgical purpose of obtaining *pure* aluminium from crude metal.

(2) Imagine an ore of aluminium in place of the soluble aluminium anodes, in the case I (1), and we have case I (2). No successful process has yet been developed on these lines, but it is not out of the range of possibility. The ores of aluminium are all non-conductors, but imagine them mixed in with the substance of a carbon anode, let us say, so that the composite anode, on being attacked by the liberated acid ingredient of the electrolyte, reforms the aluminium salt which was decomposed, and thus regenerates the solution. The voltage required for decomposition, in this case, would be practically that required to decompose the aluminium compound in the anode, and, if this compound were an oxygen compound of aluminium, would require 2·8 volts, thus entailing the simultaneous decomposition of the water (which requires 1·49 volts), and corresponding loss of power. While such processes would be very difficult to manage practically, they are, nevertheless, theoretically possible.

(3*a*) The previous case would be much simplified, if instead of the ore we could find some aluminium compound made from the ores which would be a good conductor of electricity, and could, therefore, act alone as an anode; and, particularly, if we could find one such requiring less than 1·49 volts to decompose it. I am not prepared to name such a compound, for I do not know of one; perhaps the double alkaline sulphides come the nearest of any with which we are at present acquainted. The voltage required for such salts is only 0·9, and they may possibly be conductors to some extent and stable in water. Our information on the properties of these salts is, I regret to say, very meager.

(3*b*) Aluminium ore can easily be converted into soluble salts, but it is practically out of the question to decompose such solutions with the use of *insoluble* anodes, for the reason that the voltage required for decomposition alone would, in any possible case, reach several volts, and metal could only be obtained by using very concentrated solutions, current of great density, and high voltage (and consequent great loss of power) in the process. However, using soluble anodes of another cheaper metal, placed in porous cells to prevent their salts from mixing with the aluminium salt around the cathode, the case is changed. The voltage required for decomposition in this case is only the *difference* between that required to decompose the aluminium salt, and that which would be required to decompose the corresponding salt of the other metal, which latter voltage represents the counter-electromotive force obtained by the solution of the anode. This difference of voltage, representing the voltage necessary for decomposition, would have the following values when the soluble anodes were the metals designated:

	Volts.
Zinc	0·22
Iron	0·55
Tin	0·58
Lead	0·54

If, therefore, the refining of impure aluminium in aqueous solution could be effected satisfactorily, it would apparently not be a very difficult step to extract the aluminium directly from a solution of its salt, using zinc or possibly iron for the soluble anode, and keeping the zinc or iron salt apart from the aluminium salt by a porous partition. Theory indicates such a process as being within the range of possibility.

II. Electrolysis of Fused Compounds.

(1) Refining of crude metal.

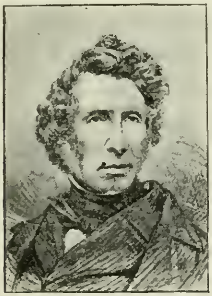
It is quite conceivable that by the use of some of the good-conducting double chlorides or double fluorides of aluminium and the alkaline metals, which melt below the fusing point of aluminium, the refining of crude aluminium, using it as the anodes, might be practised successfully; but I do not know that such an experiment has ever been made. This direction appears to me to offer great inducements for experimental work, since, by the present methods of extraction, impure aluminium can be produced direct from the ores at nearly 10 cents per pound less than pure metal. With so large a margin for profit, therefore, a suitable refining process should find a place in the industry.

(2) The only fusible ore of aluminium available for direct electrolysis is *cryolite.* If melted and electrolysed with an insoluble anode, aluminium is separated and fluorine set free (which acts on the carbon anode, forming carbon fluoride, a very disagreeable gas), while the composition of the bath is gradually changed by the elimination of aluminium fluoride, leaving it relatively richer in sodium fluoride, until at last sodium is set free and the bath practically stops working. This method of working cannot be practised commercially for several very evident reasons. Dr. Kleiner, of Zurich, tried, in 1887, to keep the bath constant by lining the decomposing vessel with bauxite, hoping that the evolved fluorine would attack and thus re-form aluminium fluoride. The regeneration, however, was very imperfect. No substance is known which, when used as an anode in electrolysing cryolite, will unite with the liberated fluorine and render it inert. This class of processes, based on the direct decomposition of cryolite, may be said to be practically inoperative, and to offer very little, if any, inducement to the investigator.

(3*a*) Converting the ore into some suitable fusible compound, and then electrolysing. This heading brings us at once to the original process by which Deville and Bunsen, in 1854, first made aluminium *en masse.* Wöhler had isolated aluminium in 1827, by decomposing aluminium chloride with metallic potassium. Bunsen had isolated magnesium by electrolysing fused magnesium chloride, and shortly after, both Deville and Bunsen, independently of each other, treated aluminium-sodium double chloride in the same way, and obtained the aluminium in considerable quantity. This salt, which melts at about 185° C., was contained in a glazed porcelain crucible, and electrolysed by the current of a primary battery, with a cathode of sheet platinum and an anode of carbon, two Bunsen cells in series (giving 3·6 volts) being found capable of decomposing the bath. As the bath is decomposed, fresh salt is fed in, and chlorine is continually evolved, while sodium chloride accumulates in the bath and finally stops the operation. Had Deville had dynamos at his command, even this imperfect process might have been developed by him into a cheaper method than his sodium process.

Quite recently, the idea has been advanced of converting the ore into the fusible double sulphide of aluminium and an alkali metal, and electrolysing this compound. The great advantages of this salt over the double chloride are, that it is much more cheaply prepared, is very stable in the air and requires less than 1 volt to decompose it. The journals have reported that the process has been worked at the Rhine Falls, Switzerland, but I can obtain no authoritative confirmation of that statement.

I know of no other fusible aluminium salt available for this direct electrolysis, although it is within the range of possibility, and even of probability, that others will be discovered and, perhaps, made available in the industry.



FREDERICK WÖHLER,
Discoverer of Aluminium,
1827.

H. ST. CLAIRE DEVILLE,
Founder of the Aluminium
Industry, 1854.

(3*b*) Dissolving the ore in a fused salt which acts as a solvent, and then electrolysing. This division of electrometallurgic processes contains the only methods by which commercial aluminium is at present being produced. The application of this principle to the production of aluminium was made independently, in the year 1886, by Héroult, in Europe, and by Hall, in America. The latter worked out the idea in commercial shape more quickly than his European rival, and was the first to put aluminium made on this principle on the market. This was in 1888.

In the process as at present practised, the solvent bath is composed of the double fluorides of aluminium and sodium. This bath may be simply cryolite, but preferably cryolite to which has been added a further proportion of aluminium fluoride and a little calcium fluoride (fluorspar). Into this bath is stirred pure alumina, made from ore by a chemical process, and which is dissolved by the bath to the extent of one-fifth of its weight. The electric current is then sent through this mixture, using for anodes carbon rods dipping into the bath from above. The cathode is formed by the carbon lining of the vessel, on the bottom of which the melted aluminium collects. When the dissolved alumina has nearly all been removed, the resistance of the bath rises, and fluorine fumes, from the decomposition of the solvent, begin to appear; fresh alumina is then stirred in, and the operation thus proceeds continuously. *Fig. 1** is a view of the interior of one of the pot rooms of the Pittsburgh Reduction Company, which works the Hall process. The pot is of boiler iron, having a thick lining of hard-baked carbon. It is made the negative electrode. The heavy copper bar above conveys the positive current, heavy carbon cylinders dipping into the fused material serving as the immediate positive electrodes, being connected with the copper bar by copper rods and cast-iron screw clamps. The whole is set on bricks, to ensure circulation of air, and thus to prevent the bottom from getting overheated. The boxes against the wall contain delicate voltmeters, which, by showing an increased potential absorbed by the pot, indicate at once to the workman the necessity of stirring in a fresh supply of alumina. *Fig. 2* is a sketch (not drawn to scale) of a vertical longitudinal section of one of these pots, with its several attachments. The several parts may be distinguished as follows:

S, iron shell; *N*, negative conductor; *L*, carbon lining, negative electrode; *P*, positive conductor; *A*, Screw clamps; *D*, copper rods; *C*, carbon cylinders, positive electrode; *F*, fused bath; *E*, cover of carbon dust.

---

* For the use of *Figs. 1* and *3* the *Journal* is indebted to the courtesy of *Cassier's Magazine*.

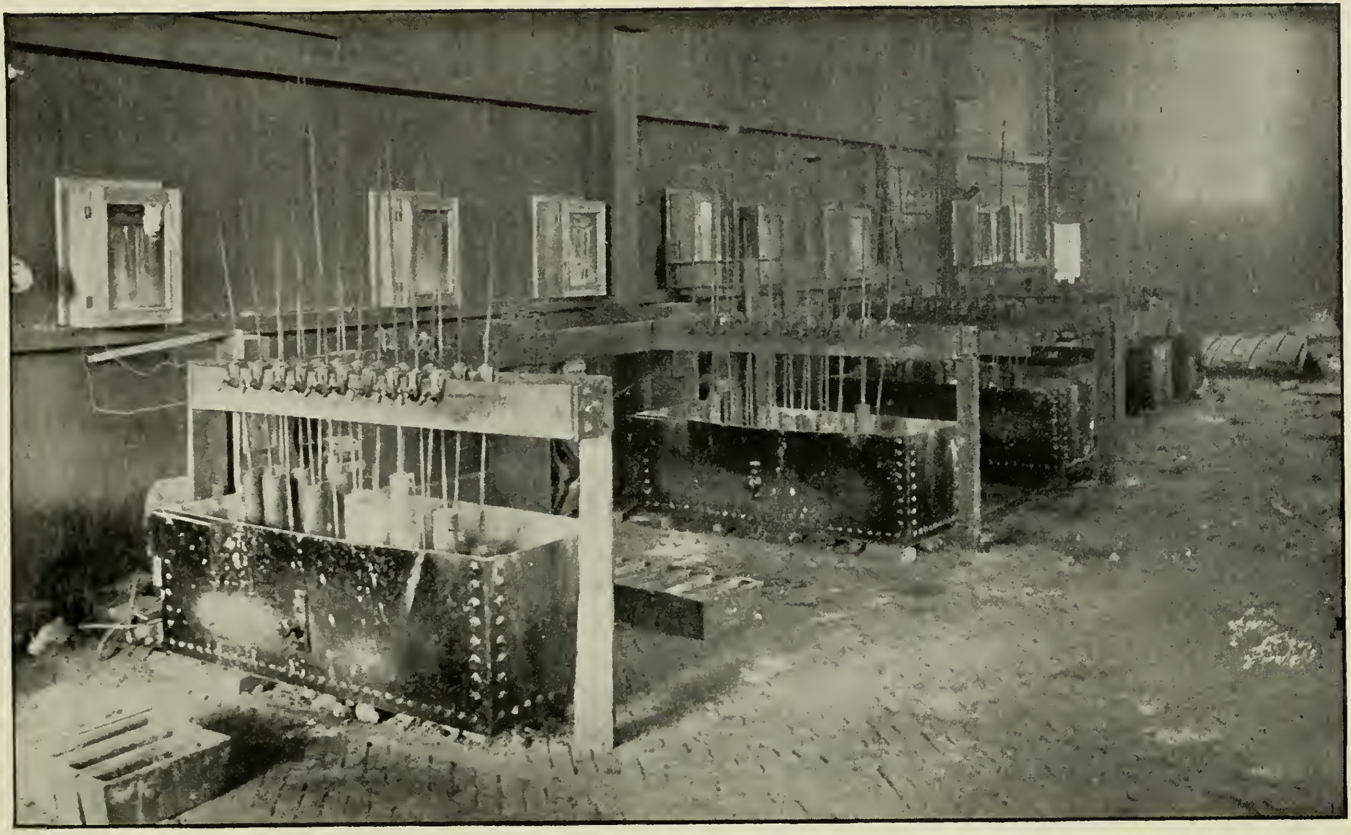


FIG. 1.—THE HALL ELECTROLYTIC PROCESS FOR ALUMINIUM. VIEW OF THE INTERIOR OF ONE OF THE POT-ROOMS OF THE PITTSBURGH REDUCTION COMPANY.

The cavity containing the fused salt has a sump in which the molten metal collects, and from which it is removed by ladles.

The ingredients present in the bath and the relative potentials necessary to decompose them are as follows:

	Volts.
Alumina	2·8
Aluminium fluoride	4·0
Sodium fluoride	4·7

The action of the current, when not of too high a voltage, is to decompose only the alumina, as long as it is present in the bath in sufficient amount. The oxygen simply combines with the carbon anodes and passes away as carbonic oxide.

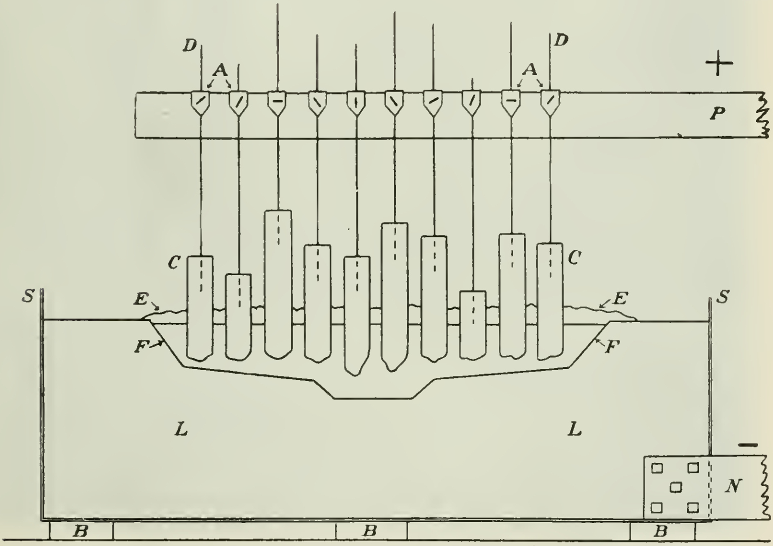


FIG. 2.—Vertical section of pot for operating the Hall process.

We can calculate easily what the practical output is in such a process. Assuming that a pot absorbs on the average 6 volts, then we have a current of 1 ampère moved by a potential of 6 volts, equal to 6 watts of electrical work, capable, as we have before stated, of separating $\frac{1}{4}$ ounce of aluminium in twenty-four hours. But 746 watts constitute the electrical equivalent of an English horse-power; therefore, 1 horse-power should be capable of separating

$$\frac{1}{4} \times \frac{746}{6} = 31{\cdot}5 \text{ ounces per 24 hours;}$$

and, if we assume an efficiency of 80 per cent. in the operation, we should still obtain 1½ pounds of aluminium per day per electrical horse-power used.

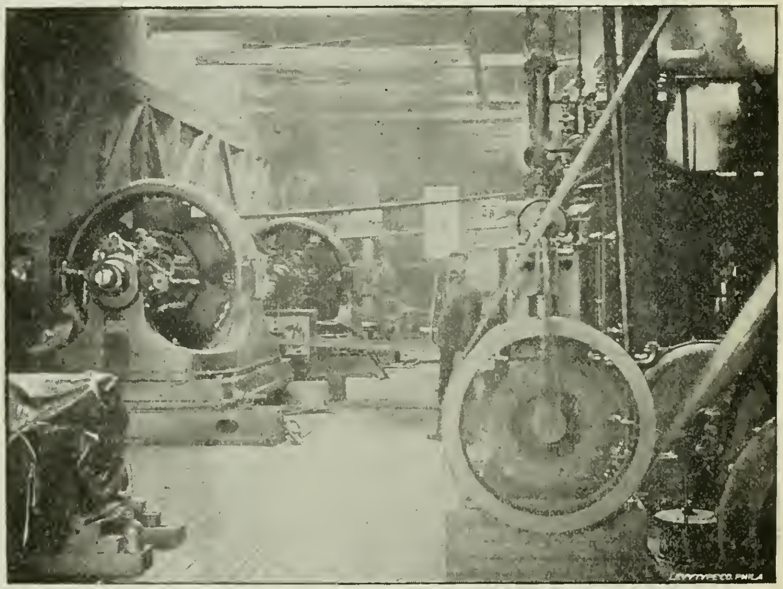


FIG. 3.—Interior of engine and dynamo room in the plant at New Kensington, Pa.

The plants now engaged in making aluminium on this principle are the following:

The Pittsburgh Reduction Company's plant at New Kensington, Pa., on the Allegheny River, near Pittsburgh. This plant is run by steam-power, the coal used costing only 65 cents per ton; and, no doubt, is conducted as economically as any steam-power plant possibly could be, with our present means and knowledge.

Fig. 3 shows the interior of the engine and dynamo room, showing the new, six-pole, 600 horse-power Westinghouse dynamos, and further off two dynamos of different type, driven by Westinghouse automatic engines.

The force employed at the Kensington plant is approximately 1,500 horse-power, and the output averages 2,000 pounds per day. At the same place the company has a rolling mill for making all sorts of plates, bars, beams and sheet, and is at present installing a new set of rolls driven by a 1,500 horse-power engine, which will be capable of rolling aluminium plates and sheets up to 8 feet in width. The purified alumina used by this company is partly imported from Germany and partly of domestic manufacture. The company also practically owns the largest of the Georgia bauxite deposits.

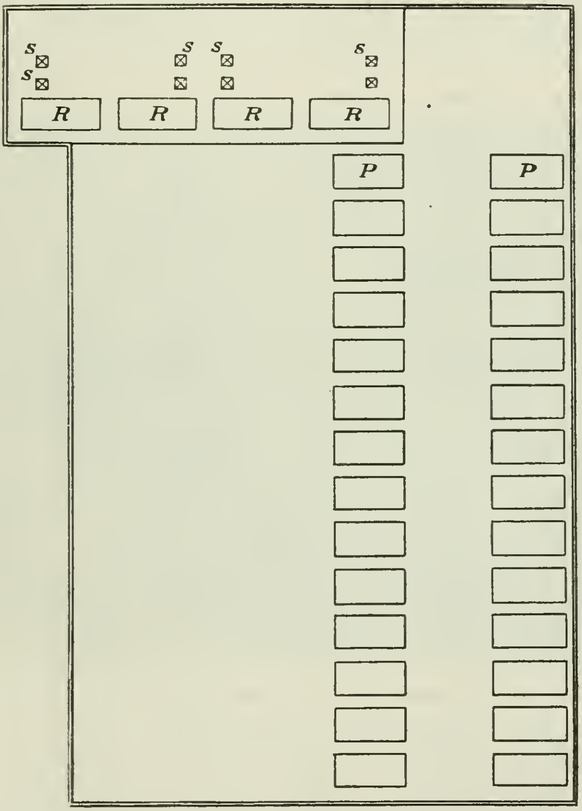


FIG. 4.—Sketch of plan of plant at Niagara Falls.

This company has had in operation, since July, 1895, a reduction plant at Niagara Falls. It is on the land of the Niagara Falls Power Company, a quarter of a mile above the new power-house. The alternating electric current of 2,500 volts potential and 500 ampères quantity (1,700 electric horse-power) is carried to the reduction works through an underground conduit. It then passes through six static transformers, which transform the current from 2,500 to 115 volts, at the same time correspondingly increasing the ampères, the loss in transformation being about 3 per cent. The currents from each pair of these transformers are passed into rotary transformers, each of 500 horse-power, each of which receives the alternating current of 115 volts by 3,600 ampères from a pair of static transformers and converts it into a direct current of 160 volts by 2,500 ampères, with a a loss of another 3 per cent. Three of these rotary transformers, run in parallel, give a current of 7,500 ampéres, which is conducted, on heavy copper bars of 8 square inches section, to the pot room. Here the current is passed through a series of thirty pots, the total output being a little over 1 ton of aluminium per day.

Fig. 4 is a sketch of the arrangement of the plant, showing, at the upper corner, the transformer room with its four pairs of static transformers *S*, *S*, and four rotary transformers *R*, *R*. Three of the four sets are in continuous operation, the fourth being held in reserve. In the pot room, arranged in a double row, are thirty reducing pots, *P*, *P*, the current passing down one row and returning up the other. The proposed enlargement will consist in rebuilding each of the 500 horse-power rotary transformers to 800 horse-power each, and adding a fifth one of like capacity. This will double the power, and the unoccupied half of the pot room will then be stocked with a duplicate set of pots. The capacity of the enlarged plant will be 2½ tons of aluminium per day.

The same company is also building a works on the land of the Hydraulic Power Company, of Niagara, close to the edge of the gorge, where it has contracted to take 4,500 horse-power. Six large dynamos of 750 horse-power each are now being built for this plant by the Westinghouse Electric Company, and it is probable that they will be in operation at the close of this year.

Fig. 5 shows the type of dynamo which has been chosen for this new plant, and we may safely conclude that it represents the best modern type of machine for electrolytic work. In general outline it is very similar to the famous Oerlikon dynamos built at Zurich. At the new Niagara plant, these machines will be run directly coupled to the turbines.

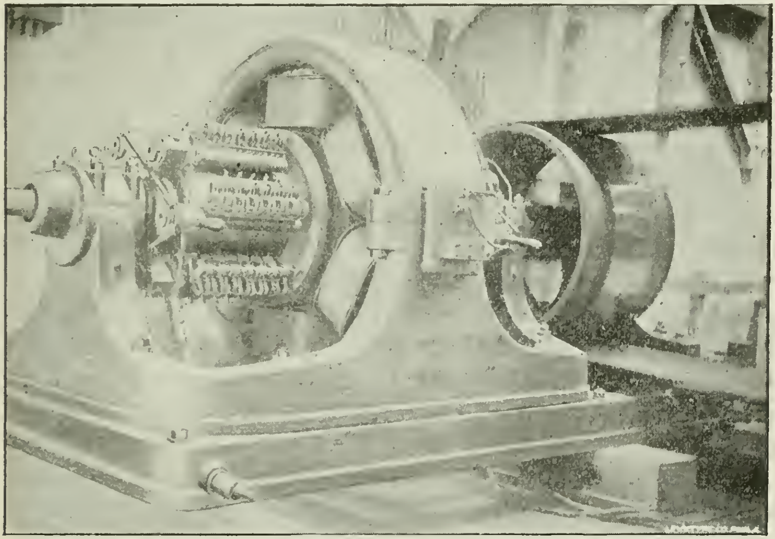


FIG. 5.—Type of dynamos to be used at the new Niagara Falls plant.

The capacity of this plant will be nearly 5,000 pounds of aluminium per day. The output of the plants of the Pittsburgh Reduction Company, now running, is, therefore, about 4,000 pounds per day, while the capacity of the works at the close of the present year, when the enlargements are completed, will be 11,000 pounds daily, or 2,000 tons per year. The officials and managers of this company deserve to be highly commended for the vigorous manner in which they have developed the industry.

In Switzerland, the works of the Aluminium Industrie

Actien-Gesellschaft, located at the Falls of the Rhine, have been in operation eight years, using the Héroult process. The company's present force is 4,000 horse-power, and its daily output 5,000 pounds of aluminium. For three years the company made only aluminium alloys with copper and iron, by Héroult's alloy process, which is described under the head of electric smelting. With the advent of cheap aluminium, the market for ready-made alloys almost disappeared, and the company, under the direction of the well-known electro-metallurgist, Dr. Martin Kiliani, began to make aluminium by Héroult's cryolite and alumina process. The principle of this process is practically identical with Hall's process. Hall says: "Melt cryolite, dissolve alumina in it, and electrolyse." Héroult says: "Flux alumina by melting cryolite with it, and then electrolyse." The processes are so similar that the United States Patent Office rejected Héroult's application, and issued the patent to Hall only. The practical operation of Héroult's process at Neuhausen is so similar to Hall's procedure, already described, that no further description of it is necessary. It may be mentioned here that the cost of all the items of raw material, labor and power is lower in Europe than in the United States, so that the present tariff of 10 cents per pound fairly represents only the difference in cost price here and abroad.

The Neuhausen Works are most picturesquely situated on the north bank of the Rhine, within a stone's throw of the famous Rhine Falls. The accompanying diagram, *Fig. 6*, shows the plan of the present works. The water has a fall of about 80 feet, and is delivered through two large pipes into a large main, from which it is distributed to the seven dynamos. The arrangement of these penstock tubes is not that which accords with the greatest economy of power, but the designers were hampered to a large extent by the situation of the plant, immediately beneath a bluff of rock. The diagram exhibits the old plant (shaded dark), which consists of a 300 horse-power turbine (third in the row), used since 1888; and two 600 horse-power turbines, in operation since 1891. The new plant (outlined) consists of four 600 horse-power turbines, used since 1893, and an extra one of the same power, since installed, which is held as a reserve. The large turbines are run by an upward current of water (Jonval type), the shaft being vertical (see *Fig.* 7).

The dynamos are on the floor above the turbines, and have as their shafts a continuation of the axle of the turbine. The armature is fixed to the shaft and revolves 150 turns per minute, while the field rings and poles are fixed. The brushes are accessible on the floor immediately above the turbine, while the field is on the floor above (*Fig.* 8). The whole construction passes through three floors or stages of the building.

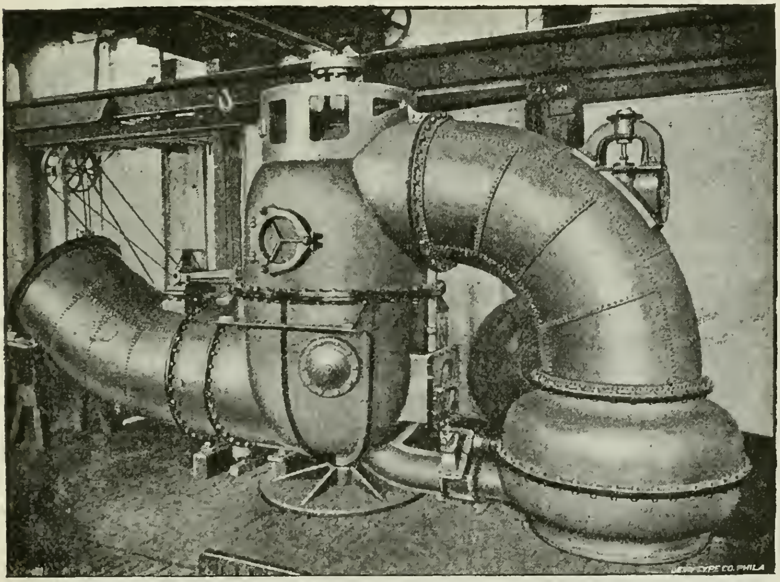


FIG. 7.—Jonval turbines used at the Rhine Falls, Switzerland.

Fig. 9 shows a nearer view of these admirable and neatly designed machines. Each generator gives a current of 7,500 ampères at a tension of 55 volts, and serves to operate a row of six pots. It appears that a greater voltage is used per pot than in our American practice. The cost of aluminium at these works is probably not over 25 cents per pound. The market price of the Neuhausen metal in 1895 was 35 cents per pound.

The Neuhausen Company has in process of erection a 10,000 horse-power plant at Rheinfelden, near Basle, which will probably be in operation in 1897. It has also acquired a water right in Austria.

In France, the Société Electro-metallurgique Française worked the Héroult process from 1889 to 1893, at Froges (Isère), and has since removed to La Praz, on the Arc, in Savoy, where it has a plant with a daily capacity of 3,000 pounds of pure aluminium. The Société Industrielle de l'Aluminium was formed in 1895, to work the Hall process in France. The company has a large works at Saint-Michel, in the Savoy, where 4,000 horse-power are available, half of which is already being utilised, and the other half will be working during 1896.

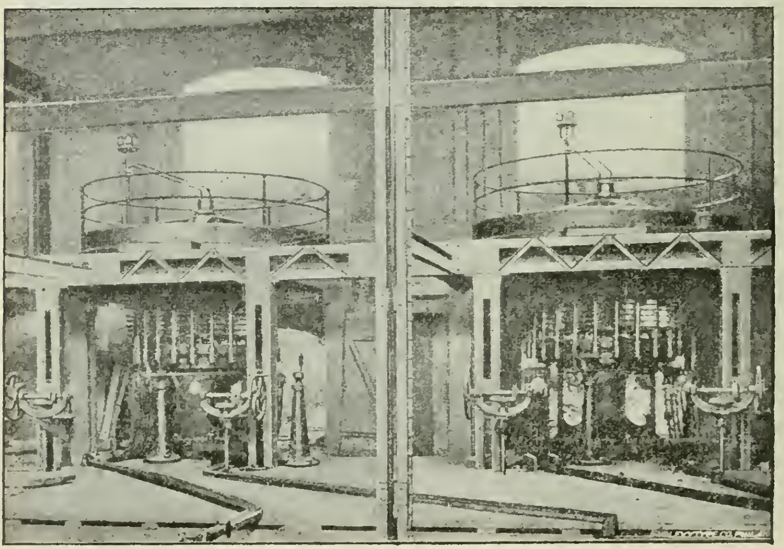
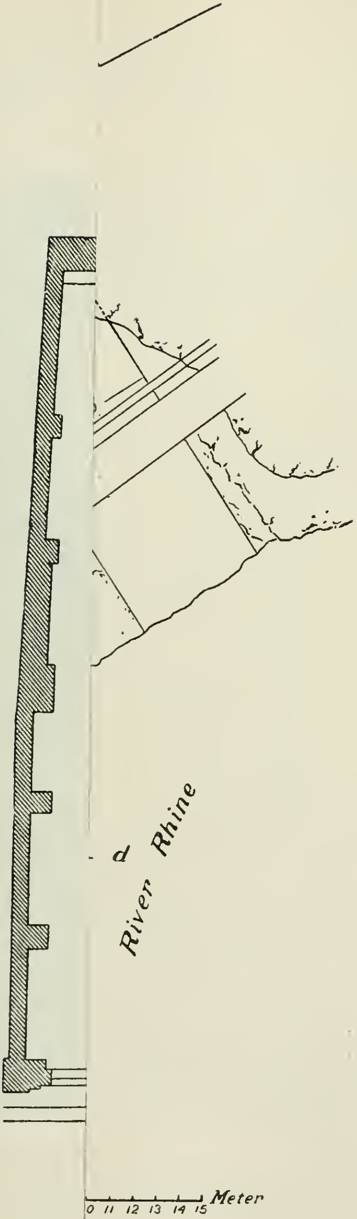


FIG. 8.—Showing the arrangement of dynamos above the Jonval turbines.

In Great Britain, the British Aluminium Company has acquired an interest in the Irish bauxite mines and erected a works to make pure alumina at Larne Harbor, near Bel-



AND.

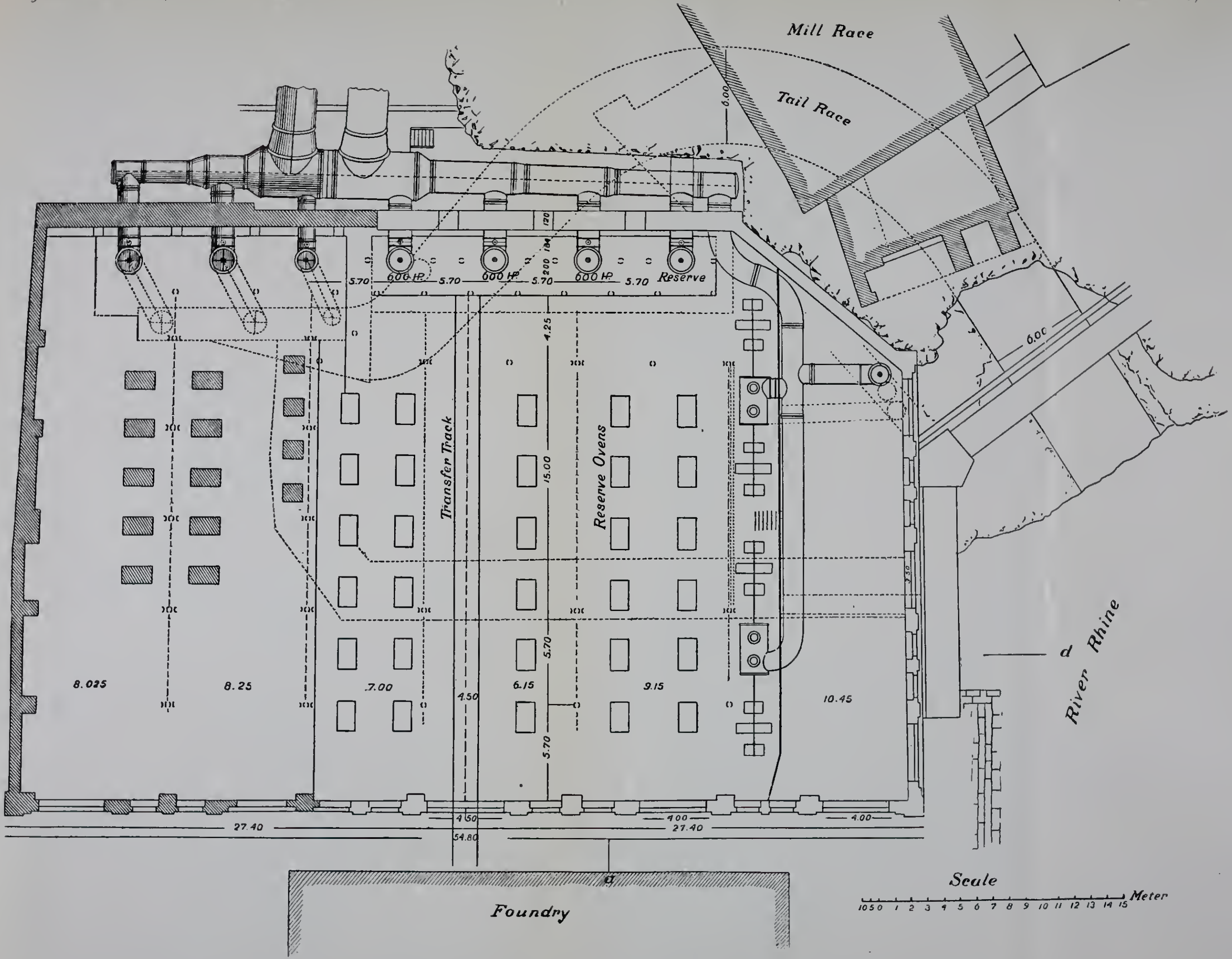


FIG. 6.—PLAN OF THE WORKS OF THE ALUMINIUM INDUSTRIE ACTIEN-GESELLSCHAFT, AT NEUHAUSEN, SWITZERLAND.

fast. The company has purchased water rights at the Falls of Foyers, in Scotland, where 4,000 horse-power will be available. It will operate by the Héroult process, and the capacity of the plant will be about 5,000 pounds per day.

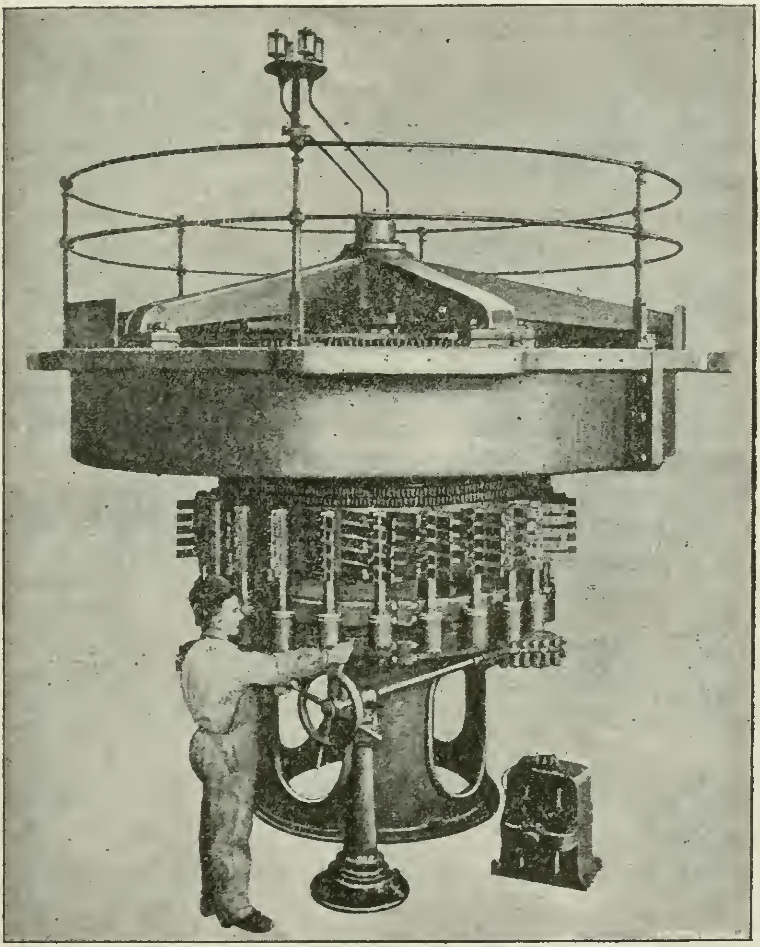


FIG. 9.—The 600 horse-power Oerlikon dynamos used at the Rhine Falls.

This plant is expected to get into operation during the present year.

In Norway, a syndicate of German and American capitalists has purchased water rights at the waterfall of Sarpsfos, on the estate of Hafslund, between Christiania and Göteborg. There is estimated to be available 10,000 horsepower, and it is purposed to have an aluminium works in operation there by 1898.

A tabular statement of the aluminium works now in operation, their power and daily capacity, is as follows:

	Horse-Power.	*Daily Capacity, Pounds.*
United States:		
New Kensington, Pa.	1,600	2,000
Niagara Falls, N. Y.	1,600	2,400
Switzerland:		
Rhine Falls	4,000	5,000
France:		
La Praz	2,500	3,000
Saint Michel	2,000	2,500
Total	11,700	14,900

This tabulation exhibits a present capacity of 2,500 tons per year; the production during 1895 was approximately 1,500 tons.

The enlargements and new plants at present projected—and which will probably be in operation in 1897, or by 1898 at the latest—are as follows:

	Horse-Power.	*Daily Capacity. Pounds.*
United States:		
Niagara Falls, N. Y.	5,500	7,000
Switzerland:		
Rheinfelden	6,000	8,000
France:		
Saint Michel	2,000	2,500
Great Britain:		
Falls of Foyers	3,000	4,000
Norway:		
Falls of Sarpsfos	5,000	6,500
Total capacity of projected plants	21,500	28,000
" " of plants in operation	11,500	14,500
Total capacity in 1898	33,000	42,500
		Tons.
Annual capacity in 1898 (in short tons)		7,650

When this production has been attained, it is quite probable that the selling price of aluminium will be as low as 25 cents per pound, at which price there are, for practical purposes, only three cheaper metals—iron, lead and zinc.

III. Electro-Thermal Processes.

Following out my classification, I am brought to a decided anti-climax. The present successful methods of producing aluminium have all been described, and this chapter must be confined to a brief allusion to processes which have outlived their usefulness.

In these processes, the current is converted as largely as possible into heat, and, at the temperature obtained, alumina is readily reduced by carbon. The Cowles Brothers used horizontal electrodes, and placed between them the mixture of alumina and carbon, using copper or iron to catch the aluminium and prevent its volatilisation.

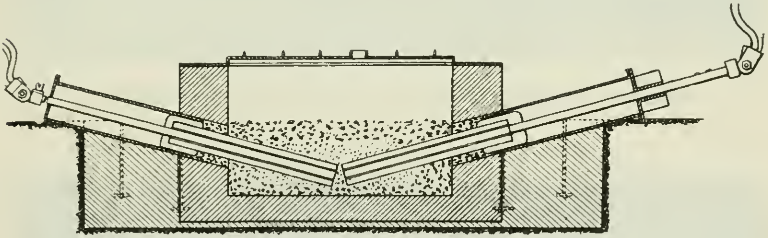


FIG. 10.—Section of Cowles alloy furnace.

Pure aluminium cannot be made in this way, for there is large loss by volatilisation and oxidation, the quality of the metal is vitiated by absorbing carbon, nitrogen and other elements present, and the metal is only obtained in the form of shot, and by an interrupted, and not a continuous, process. *Fig. 10* shows a section of the Cowles furnace, such as was operated for several years at Lockport, N. Y., and at Milton, in England. *Fig. 11* shows the exterior of the battery of furnaces at Milton.

The Héroult alloy furnace was operated for several years in Switzerland and France, and experimentally in the United States, at Boonton, N. J. It is provided with a ver-

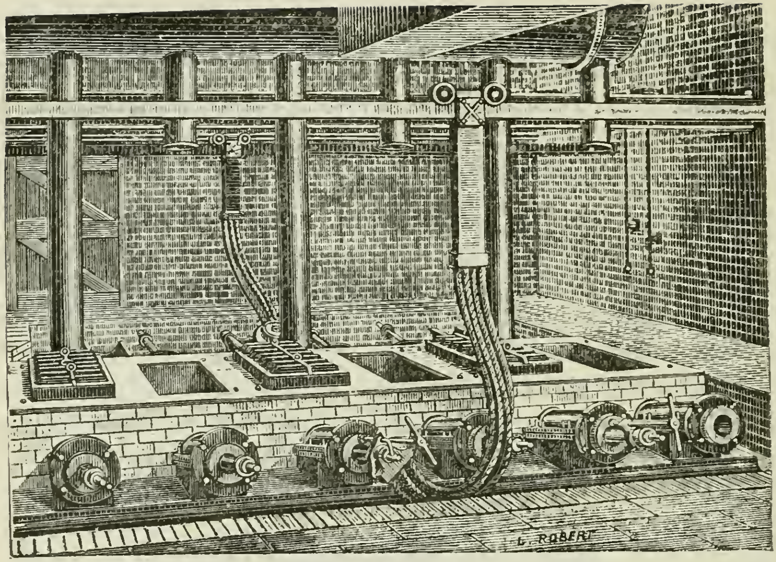


FIG. 11.—Battery of Cowles furnaces, at Milton, England.

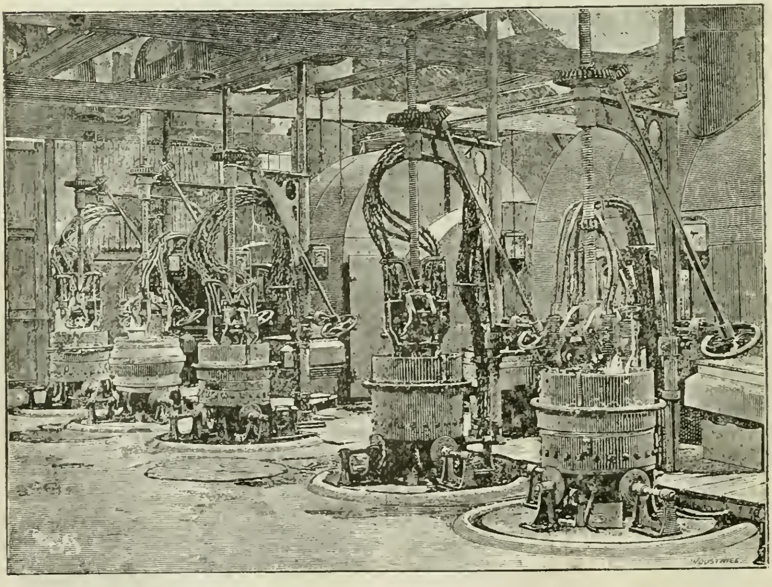


FIG. 12.—Suite of five Héroult alloy furnaces, at Froges, France.

tical anode, dipping into a cavity in a carbon-lined box, the carbon lining being the cathode. In this cavity, copper or iron is first placed, then melted by the electric arc playing between the electrodes, after which pure alumina is fed in and similarly melted until it forms a liquid bath above the copper. The greater part of the alumina is then reduced by the carbon present. Alloys only can thus be formed. *Fig. 12* shows a battery of five such furnaces, at the works at Froges, France.

So high a voltage is required to conduct these operations, and the aluminium obtained is so impure, that they cannot compete economically with the gentler and yet much more efficient *electrolytic* processes—which have entirely displaced them. The only possible way in which I can imagine the electro-thermal methods being used again in producing aluminium is in the form of huge electrical furnaces, resembling blast furnaces, in which, with the use of suitable fluxes and reducing agents, and the intense heat obtained by the electric arc, raw bauxite would be reduced on a large scale to impure aluminium, which would then be refined by a chemical or electrolytic method.

STEREOSCOPIC RÖNTGEN SHADOW PICTURES.

By Elihu Thomson

The ordinary single shadow picture, as produced by Röntgen's method, shows the position and dimensions of an object in a single plane only. The thickness, depth or relative positions of objects in a direction perpendicular to the plane of the sensitive plate are not shown or indicated in any way. Thus, in a shadow image of a hand, showing the bones with a faint covering of flesh, there would be no indication of a flexure of a finger or of its being directed upward or downward. Neither is there any indication of the actual position of the bones within the soft integuments, except in the direction of length or breadth. The third dimension is missing.

It may, however, become useful in surgery to know the actual space relations of objects involving all three dimensions. To do this, we may take advantage of the principles of stereoscopic vision as in the stereoscope, which the writer has found perfectly feasible. A moment's reflection will, however, show that stereoscopic shadows are something of a novelty in themselves. A shadow is ordinarily thrown upon a surface, and is seen simultaneously by both eyes. An ordinary shadow having no thickness cannot, of course, be seen stereoscopically. With Röntgen shadow pictures we can, however, secure stereoscopic effects in a very simple way. If we take one such picture of an object or set of objects with the Crookes tube in a certain relation to the objects and sensitive plate, then place another plate back of the objects and obtain an impression upon it with the Crookes tube somewhat displaced laterally from its first position, we obtain two stereoscopic shadow pictures, which may be used to produce prints to be viewed in the stereoscope. The shadow of a coiled spring, for example, obtained in the way mentioned, will, in the stereoscope, show the turns of the spring in relief. The bones of the hand will be seen in space surrounded by the hazy flesh, and if one or more of the fingers be flexed, the degree of flexure will be indicated. A foreign object embedded in the soft tissues would thus have its position with respect to the bones at once declared. As furnishing a background from which depths may be seen or estimated, it is well to place between the object and the sensitive plate a netting of wire with open meshes, which casts a distinct shadow. In such case the stereoscopic shadow images, when viewed stereoscopically, show the objects above the screen and at proper relative distances therefrom. This netting, or screen, also ensures the proper mounting of the pictures in relation to each other; for, should the screen be seen in the stereoscope above the objects, it would indicate that a transposition of the pictures had been made, and that for correct indications to be obtained the error must be remedied.

A number of experiments, made with a view of testing the method above described, have been made by the writer, and have given very satisfactory results. The skeletons of small animals may be thus examined in relief, and the actual position of objects embedded in solid material discovered. It is conceivable that by the use of a fluorescent screen, and two cathodes placed some distance apart in the Crookes tube, these cathodes receiving discharges alternately, and thus producing two separate displaced sources of Röntgen rays, two stereoscopic fluorescent images may be produced on the screen. If, now, shutters or diaphragms are placed between the screen and the eyes, opened and closed synchronously with the discharges, and alternately with respect to each other, the image will be seen on the screen stereoscopically. In this way, by a rapid examination, the true space relations of embedded objects may be noted.

CHEMICAL SECTION.

Stated Meeting, February 18, 1896.

DR. HARRY F. KELLER, President, in the chair.

A SOURCE OF ERROR IN THE DETERMINATION OF PHOSPHORIC ACID BY THE CITRATE METHOD.

BY FRANCIS BERGAMI.

The citrate method of phosphoric acid determination has been highly recommended for the analysis of superphosphates, basic slag and mineral phosphates by so many chemists of renown that its applicability can hardly be doubted—at least, not to agricultural analysis. Still, some analysts assert that this method has failed to show satisfactory results in their hands, especially on mineral phosphates.

A great number of tests made during the last year have led me to believe that this failure, in many cases, is due chiefly to a delay of the filtration of the ammonium-magnesium precipitate. In making a series of comparative tests, I did not, for a long time, encounter any serious difference between the citrate and molybdate methods, until once I was compelled, in the analysis of a sample of South Carolina phosphate, to let the ammonium-magnesium precipitate stand over night; while, in all previous cases, excepting some tests on citrate-insoluble phosphoric acid, the filtration had been executed either immediately after the precipitation, or not any later than about three hours thereafter.

The results obtained on this sample were: citrate method, 29·60 per cent.; molybdate method, 28·32 per cent. The test was repeated by the citrate method, with the result 28·48 per cent. As in this latter test the filtration of the ammonium-magnesium precipitate had been executed immediately after the precipitation, I suspected that the high result of the first test had been caused by the delay of the filtration. To ascertain the correctness of this suspicion, several other tests were made, and the fact was thereby established that results obtained by filtration, immediately, or only a short time after precipitation, agree very well with the molybdate method; while those obtained by filtration, after about fifteen hours, are entirely too high. A close observation during those tests showed that the filtrate from the magnesium precipitate, when obtained at once after precipitation, remained perfectly clear for about four hours, after which time a slight turbidity appeared, which increased more and more until, after standing over night, a small precipitate of silica and aluminum and iron oxide had formed. In all filtrates from precipitates which had stood over night, no after-precipitation could be observed.

Of the numerous tests made, the following show the most remarkable figures:

Acidified South Carolina Rock:

	Per Cent.
Molybdate method	16·00
Citrate method (filtration after two hours)	15·92
Citrate method (filtration after fifteen hours)	16·96

Florida Phosphate:

	Per Cent.
Molybdate method	32·16
Citrate method (filtration immediately after precipitation)	32·32
Citrate method (filtration after fifteen hours)	33·92

It has been claimed that, by using concentrated sulphuric acid as a solvent, not only a large amount of calcium oxide, but of aluminum oxide, also, is precipitated. Hoping to at least reduce the error, I treated some samples with 50 cubic centimeters of concentrated sulphuric acid, boiling for thirty minutes, but failed to get any other results than those obtained by the use of hydrochloric and nitric acids.

In the determination of the citrate-insoluble phosphoric acid of acidified mineral phosphates, the danger of getting high results by a delay of the filtration is not so great, as a considerable amount of silica, iron and aluminum oxides is removed by the action of the neutral citrate of ammonium solution at 65° C.; yet, on some samples, results become entirely too high.

From my experience in the citrate method, I have come to the conclusion that the general direction to filter the magnesium precipitate, either right after precipitation or at any later time, holds good only for the determination of the water-soluble phosphoric acid of superphosphates and the insoluble phosphoric acid of animal phosphates, such as bone-meal, and bone-black. In the determination of the insoluble phosphoric acid of mineral phosphates, their superphosphates, and all mixtures containing the same, the filtration of the magnesium precipitate must take place either immediately after the precipitation, or not any later than three hours afterwards, if a contamination by silica and aluminum and iron oxides shall be avoided. With this precaution, however, excellent results can be obtained by the citrate method, provided an appropriate amount of citrate of ammonium solution is used.

According to my experience, the best results are obtained by using 0·4 grams of substance and 75 cubic centimeters of citrate solution in the determination of total phosphoric acid. For the citrate-insoluble phosphoric acid, 0·4 grams of substance and 40 cubic centimeters of citrate solution have proved, in my hands, to give the most satisfactory results.

STANDARDISING OF NORMAL ACID BY BORAX.

By Francis Bergami.

More than thirty years ago, Th. Salzer recommended the use of borax for the alkalimetric measurement of acids, but his proposition attracted very little attention until E. Rimbach[1] published his work on the determination of the atomic weight of boron. Since that time, several other chemists have tried to introduce the use of borax for the standardising of normal acid, but they all propose either methyl orange or litmus as indicators for this purpose. Mr. L. F. Kebler stated some time ago, before the Chemical Section of the Franklin Institute, that methyl orange proved to be of inferior value in his hands, as well as in the hands of other chemists. Litmus enables one to obtain satisfactory results, but it requires a great deal of practice, as the change of color in borax solutions is not as distinct as could be desired for routine work, especially by inexperienced workers. I am, therefore, surprised that so little attention seems to have been paid to the researches of Robert T. Thomson,[2] on larmoid.

Thomson found that larmoid, while its properties as an indicator are nearly the same as those of methyl orange, excels the latter substance by far in regard to sensitiveness, and allows an absolutely correct titration of the alkali in borax solution. A double recrystallisation of the commercial c. p. borax yields a strictly pure product, and, by the aid of this and larmoid as indicator, the standardising of normal acid becomes not only a very convenient, but also an extremely accurate operation.

---

[1] *Fresenius' Zeitschrift*, **32**, 526.

[2] *Chem. News*, **51**, 18.

HENRY BOWER.

The Board of Managers reports, with sincere regret, the loss, by death, of one of its members, Henry Bower, who died on March 26, 1896.

Mr. Bower was so conspicuously active and so earnest in the several efforts that have lately been made in behalf of a new building for the Institute, that the Board feels that it is proper to place on record its warm appreciation of its deceased member's zeal and interest in promoting the welfare of the Franklin Institute.

Mr. Bower was born in Philadelphia, in 1833, and was graduated from the Philadelphia College of Pharmacy in 1854. He engaged for a time in the business of broker in chemicals, and, in 1856, began the manufacture of chemicals at Twenty-ninth Street and Gray's Ferry Road, where the works which he established are at present located.

Throughout his active business career he was prominently identified with every movement affecting the growth of the chemical industry in the United States. He was the first in this country to use potash salts as an ingredient of the fertilisers which he manufactured; also, he was among the first—if not the first—to recover, on the large scale, the ammonia from the "gas liquors" of the gas works.

He received from the Franklin Institute, in 1878, the Elliott Cresson Medal, as the first in this country to make pure inodorous glycerine. He received, also, medals for the excellence of his manufactures, at the exhibitions of Vienna, 1873; Franklin Institute, 1874; Philadelphia, 1876; Paris, 1878; and Chicago, 1893.

It was chiefly owing to his representations that the U. S. Census Bureau determined, in the Census of 1880, to have the statistics of the chemical industry reported as a separate branch of manufactures. Mr. Bower was appointed the special agent of the Bureau to collect these statistics for the Census of 1880 and 1890, and the excellence of these reports bears eloquent testimony to the painstaking and thoroughness with which he devoted himself to the work entrusted to his hands. His intimate acquaintance with the chemical industry of the United States was widely recognised, and the fact that his opinions and advice were frequently sought by the committees of the Senate and House of Representatives in the framing of tariff legislation bearing thereon, affords capital evidence of the extent and accuracy of his knowledge of the subject and of the soundness of his judgment. He was prominent in the councils of the Manufacturing Chemists' Association of the United States, and served this body for many years as secretary and treasurer.

Mr. Bower was elected a member of the Franklin Institute in 1858, was chosen a member of the Board of Managers in 1891, and was continued in this position until his connection was severed by death.

His associates in the Board present this brief tribute to the memory of their late associate to the Institute, whose welfare was always near to his heart, with the suggestion that it be printed in the *Journal.*

By order of the Board,

JOSEPH M. WILSON, *President.*

NOTES AND COMMENTS.*

A CONDUIT ELECTRIC ROAD IN WINTER.

The *Iron Age* has the following comments on the experimental piece of underground electric railway in New York, which has gone through the severe service of the past winter:

The underground road which the General Electric Company installed on Lenox Avenue, New York, has emerged successfully from the tests to which the severe snowstorms of the last month have subjected it. During the violent snowstorm of March 11th the operation of the road did not cease. The snow began to fall about 8 o'clock in the morning and the snow sweeper was started out over the line, but before it could make the complete trip the sprocket wheels of the broom broke, and it was necessary to push the sweeper back into the barn for repairs. Not until 4 o'clock in the afternoon was it ready to go out on the tracks again. Meanwhile the service of the road was conducted without any stoppage, and the cars ran over the unswept tracks with no greater delay than would ordinarily be caused by considerable slipping of the car wheels on the snow-covered rails. It took about eight or ten minutes longer to make the trip. At some points on the line the snow was swept by the wind into drifts, making it necessary for the motorman to back his car to get the necessary momentum to push his vehicle through the drifted snow. At 4 o'clock the snow sweeper cleared the line of the snow and regular schedule time was again resumed. About 8 o'clock the storm turned to sleet and hail, and, as it fell, covered the rails with ice. Notwithstanding this the cars ran under their usual headway. On the Lexington Avenue Electric Conduit Road a gang of men swept the tracks, and on this line the cars made schedule time while the bad weather prevailed. Throughout the duration of the storm no electrical trouble of any kind was developed either in the conduit or in the cars. The rolling stock of the electric conduit lines of the Metropolitan Traction Company is now undergoing a large increase. Equipment has been started on a number of new cars.

---

* From the Secretary's monthly reports.

THE SIMPLON TUNNEL.

After a varying lapse of time, the necessity of additional means of communication between the countries north of the Alps and Italy makes itself felt; and just so sure as that the Mont Cenis Tunnel would be followed by that of the St. Gothard, but whether in ten, fifteen or twenty years, could not be foretold at the time, so it was equally certain that the Alps would once more be pierced at the Simplon. The constructors guarantee the necessary installations, the completion of the first tunnel, and the gallery, for the fixed sum of 54,500,000 francs, and the completion of the gallery by turning it into the second tunnel, with a permanent way, for an additional 15,000,000 francs. From the time the traffic begins, ventilators will be used to renew the air of the tunnel and to reduce the quantity of carbonic acid caused by the locomotives. Each train, after passing through, will close automatically the door of the tunnel, and air will be driven into the same by suitable side passages. The need of ventilation from tunnel No. 2 will, of course, have ceased.

The advantages of the Simplon as an international route consist not only in the reduction of distance between Calais and Milan, but specially in the conditions of level, which are much more favorable than in the Mont Cenis and the St. Gothard. The culminating point in the three tunnels is stated thus:

	Meters.
Mont Cenis	1,294·70
St. Gothard	1,154·60
Simplon	705·20

The project of a railway tunnel under the Simplon has occupied the attention of engineers and experts for the last thirty-five years. The scheme has been delayed by the piercing of the Alps at the Mont Cenis and the St. Gothard, but its accomplishment now seems assured. An agreement to this effect was signed between Switzerland and Italy on November 25th last; the necessary subventions are guaranteed on both sides; and a definite offer from a syndicate of contractors of the highest repute to construct the tunnel for a fixed sum will facilitate the contribution of 40,000,000 francs, which must be furnished by private capital.

The tunnel, which will pass under the massif of Monte Leone between Brigue (Switzerland) and Issela (Italy), will be 19,731 meters long, and its highest point in the interior 705 meters 20 centimeters above the sea-level, with a downward slope in both directions of 1 meter in every 50 towards Brigue and 1 in 143 towards Issela. The principal difficulty in piercing the tunnel will consist in the very high temperature—40° C.—in that part of the route which lies deepest under the mountain, and, therefore, the authors of the project have adopted a new system in piercing it, which is very ingenious. The mountain will be tunneled by two parallel passages at a distance from each other of 17 meters. The first tunnel will be completely finished so as to admit a single line of rails of the normal gauge; the second tunnel will serve as a gallery, and will only be completed so as to admit the double line some years after the completion of the first. This gallery, with its transverse galleries connecting it at every 200 meters with tunnel No. 1, will serve for ventilation, the arrival of ballast trains and other working material, for conducting water at high pressure and laying down electricity for lighting purposes. The transverse galleries will be closed by doors, but the advanced transverse galleries which are nearest the workings, when the piercing of the rock is being pushed forward, will be left open. This door will prevent the current of air from passing through the earlier passages and secure a good ventilation at the actual spot where the workings are furthest advanced.

This draught will then pass through the two advanced transverse galleries and will return by tunnel No. 1. While one of these cross galleries is being pierced, of course there can be no current of air through it; in this case the air will be forced in by means of injectors. The temperature already lowered by the fresh air from the ventilators will further be closed by jets of cold water spray. After each case of blasting the *débris* will be cleared away by hydraulic force, and the Brandt perforators used to pierce the rock will also be worked by the same power. The geological formation of the mountain is favorable to the work, as gneiss chiefly will be met with. The motive force will be supplied at Brigue by the Rhone, and at Issela by the Diveria or the Cairasca. A boring of 700 meters at Berisal above the tunnel will serve for the passage of the water of the Steinenbach, which will supply hydraulic force by its own natural pressure.—*Engineering and Mining Journal.*

THE CARBIDE-ACETYLENE PROBLEM,

which has been the subject of so much and such diverse criticism, is now being made the subject of an exhaustive practical investigation at the hands of a scientific commission composed of electrical and chemical experts selected for the purpose by our enterprising contemporary, *Progressive Age.*

The estimates of cost of production have varied so widely that would-be investors interested in the new gas have conservatively held aloof, and until the commercial possibilities of the new method have been thoroughly investigated, and established beyond reasonable doubt, such hesitation will continue.

The *Progressive Age*, in undertaking this investigation, deserves the thanks of all who are interested in gas or electric light enterprises, and if the promise held out by its editor be fulfilled, he will have placed the gas and electric fraternity under great obligations.

It only remains for us to add that the experts selected for this responsible work are, on the electrical side of the question, the well-known electrical engineers, Drs. Houston and Kennelly, while the chemical phases of the subject will be reported upon by Dr. Leonard P. Kinnicutt, of the Worcester Polytechnic Institute.

It is stated that the arrangement made on behalf of the experts involves a personal investigation of the works of the Willson Company at Spray, N. C., which will be turned over to them absolutely during the continuance of the proposed tests. W.

GROWTH OF AMERICAN IRON AND STEEL PRODUCTION.

The directory of the iron and steel works of the United States, which is published every two years under the auspices of the American Iron and Steel Association, has just been issued. Its contents bear very striking testimony to the expansion of a department of national industry which has reached proportions unequaled in any other country of the world. Twenty years ago, says the *Boston Herald*, the capacity of the blast furnaces of the United States was 4,856,455 tons; to-day it is 17,373,637 tons. But for the output of 1876, 713 furnaces were required, while for that of 1896, 469 furnaces are adequate. The average annual capacity of the blast furnace of twenty years ago was 6,811 gross tons, while to-day it is 37,044 tons. A still more striking evidence of the revolution that has taken place in the methods of iron production may be found in the fact that the four new furnaces now being constructed for the Carnegie Steel Company will have an aggregate annual capacity of 700,000 tons, or 175,000 tons each. These will be the largest furnaces in the world, and it is significant of the change that has come over the trade since 1894, that while in that year not one new furnace was building in this country, there are to day, besides these gigantic four, twenty other new furnaces either in construction or projected. A steadily decreasing number of blast furnaces use charcoal, the proportion being reduced to less than 6 per cent. of the whole; for the rest, coal and coke serve as fuel. The directory enumerates and describes 505 rolling mills and steel works, the annual converting capacity of all the standard Bessemer steel plants in January last, built and building, being 9,472,350 tons of ingots and direct castings, against 7,740,000 tons in January, 1894. Of the open-hearth steel plants at work or in construction, the annual capacity is 2,430,450 tons, against 1,740,000 tons two years ago. It thus appears that, while the increase in the capacity of the Bessemer steel plants has been 18 per cent. in two years, that of the open-hearth steel plants has been 28 per cent. Evidence of the production-restricting policy of the nail trust will be found in the fact that while in January, 1892, there were 65 rolling mills devoted in whole or in part to the manufacture of cut nails and spikes, and containing 5,546 nail machines, the number had decreased, by January, 1894, to 55 mills and 5,094 machines, and in January, 1896, to 53 mills and 4,598 machines. A decrease of 948 nail machines in two years, side by side with a great increase of capacity in every other branch of the iron and steel industry, is a fact replete with significance, and to be only partially offset by the increased output of the wire nail works.

It further appears from the directory that there are 74 iron and steel bridge-building works in the United States, 22 locomotive works, 36 iron and steel ship building yards, 64 completed car-axle works and 2 building, 112 completed car-wheel works and 1 partly erected, and 112 car-building works. In addition to these, there are 13 horse nail-works, 82 malleable-iron works, 70 cast-iron and cast-steel pipe works, and 38 wrought-iron and wrought-steel pipe, iron- and steel-riveted pipe and seamless-tube works. These are but part of the many establishments in which the cruder iron and steel materials are taken up and developed into more or less finished products, but even their bare enumeration gives an impressive idea of the magnitude of this branch of American manufactures.

STEEL WOOL is an interesting product, the subject of a recent German patent, and is intended for use in all cases where sandpaper, emery paper, pumice stone and materials of a kindred nature are employed. In bulk it resembles, both in appearance and to the touch, the hair commonly used for stuffing mattresses and chairs. The ordinary by-product known as steel shavings has for many years been used for rough work, in which the coarser grades of sandpaper are used; but the objections to the use of these shavings for the finer work of rubbing down varnish or paint on woods and for polishing metals were the harshness of, and lack of uniformity in, the threads, and the edges of the shavings being very sharp, thereby cutting instead of polishing; and, being of many different sizes and shapes, would leave an uneven surface. The *Railroad Gazette* says that the idea of making a machine to overcome these difficulties originated years ago in Switzerland with an observing German, who noticed painters gathering the refuse derived from the manufacture of reed for looms, and picking therefrom the finer grades for use in rubbing down wood and metal work generally. Upon examination he found that this residue consisted of flat ribbons of steel, the borders of which were planed off, and before being assorted was an admixture of fine and coarse grades. He readily discovered two defects in the material thus obtained: first, it was impossible to obtain any appreciable quantity of a uniform grade, and, secondly, the temper and quality of the steel were such that only indifferent results could be obtained from its use. Eventually he built a machine for the manufacture of shredded steel or steel threads uniformly fine in quality, but still retaining sufficient cutting propensi-

THE MINERAL PRODUCTION OF THE UNITED STATES IN 1895.

The accompanying table, exhibiting the amounts and values of the various mineral products of the United States for the year 1895, we are enabled to present to our readers by courtesy of Mr. R. P. Rothwell, editor, from advance sheets of "The Mineral Industry," Vol. IV, shortly to appear.

W. H. W.

MINERAL PRODUCTION OF THE UNITED STATES IN 1894–95.

Compiled for The Mineral Industry, Vol. IV.,

By Richard P. Rothwell, editor of the *Engineering and Mining Journal.*

No.	Products.	Customary Measures.	1894.			1895.		
			Quantity.		Value at Place of Production.	Quantity.		Value at Place of Production.
			Customary Measures.	Metric Tons.		Customary Measures.	Metric Tons.	
	Non-Metallic.							
	Abrasives—							
1	Corundum and emery...	Short tons....	1,120	1,106	$109,500	385	349	$56,400
2	Garnet....	Short tons....	1,000	907	35,000	2,065	1,873	93,350
3	Grindstones	Short tons....	29,989	27,200	257,596	36,389	33,004	290,378
4	Millstones	Short tons....	297	269	4,447	105	95	8,525
5	Tripoli and infus. earth..	Short tons....	1,663	1,508	22,825	1,788	1,622	26,049
6	Whetstones.............	Short tons....	1,735	1,574	84,450	1,609	1,459	78,303
7	Alum	Short tons....	72,000	65,304	2,160,000	75,000	68,025	2,225,000
8	Antimony ore............	Short tons....	165	150	9,075	1,083	982	37,905
	Asbestos and talc—							

(*a*) Bituminous coal includes brown coal and lignite. Arkansas, and Colorado. (*b*) Estimated. (*c*) Kilograms.

THE MINERAL PRODUCTION OF THE UNITED STATES IN 1895.

The accompanying table, exhibiting the amounts and values of the various mineral products of the United States for the year 1895, we are enabled to present to our readers by courtesy of Mr. R. P. Rothwell, editor, from advance sheets of "The Mineral Industry," Vol. IV, shortly to appear.

W. H. W.

MINERAL PRODUCTION OF THE UNITED STATES IN 1894–95.

Compiled for The Mineral Industry, Vol. IV.,

By Richard P. Rothwell, editor of the *Engineering and Mining Journal.*

No.	Products.	Customary Measures.	1894.			1895.		
			Quantity. Customary Measures.	Quantity. Metric Tons.	Value at Place of Production.	Quantity. Customary Measures.	Quantity. Metric Tons.	Value at Place of Production.
	NON-METALLIC.							
	Abrasives—							
1	Corundum and emery	Short tons	1,120	1,106	$109,500	385	349	$56,400
2	Garnet	Short tons	1,000	907	35,000	2,065	1,873	93,350
3	Grindstones	Short tons	29,989	27,200	257,596	36,389	33,004	290,378
4	Millstones	Short tons	297	269	4,447	105	95	8,525
5	Tripoli and infus. earth	Short tons	1,663	1,508	22,825	1,788	1,622	26,049
6	Whetstones	Short tons	1,735	1,574	84,450	1,609	1,459	78,303
7	Alum	Short tons	72,000	65,304	2,160,000	75,000	68,025	2,225,000
8	Antimony ore	Short tons	165	150	9,075	1,083	982	37,905
	Asbestos and talc—							
9	Asbestos	Short tons	265	240	4,350	1,010	916	11,400
10	Fibrous talc	Short tons	50,500	45,804	505,000	66,500	60,316	665,000
11	Talc and soapstone	Short tons	21,044	19,087	401,892	18,885	17,129	361,353
12	Asphalt	Short tons	4,198	4,080	75,654	14,300	12,970	300,000
13	Bituminous rock	Short tons	34,199	31,018	148,120	43,778	39,707	143,456
14	Barytes	Short tons	23,758	21,548	95,032	20,255	18,371	99,020
15	Bauxite	Long tons	10,732	10,908	42,928	14,145	14,371	56,580
16	Borax	Pounds	13,140,584	5,962	919,841	13,506,356	6,126	742,850
17	Bromine	Pounds	379,444	172	98,655	394,854	179	102,662
18	Cement, natural hydraulic	Bbls., 300 lbs.	7,813,766	1,064,297	4,455,928	7,694,053	1,047,006	4,597,285
19	Cement, Portland	Bbls., 400 lbs.	611,229	110,877	1,209,446	749,059	135,879	1,430,089
20	Clay, refractory	Short tons	3,375,738	3,061,794	4,050,885	*b*3,750,000	3,401,250	4,500,000
21	Clay, kaolin	Short tons	24,552	22,246	185,169	30,910	28,035	258,431
22	Coal, anthracite	Short tons	*a*52,010,433	47,183,345	80,879,404	*a*58,362,985	52,965,538	89,948,699
23	Coal, bituminous	Short tons	*a*117,865,348	106,903,871	103,758,967	*a*138,079,466	125,247,053	125,489,488
24	Coke	Short tons	8,495,295	7,706,846	12,654,558	9,927,348	9,006,090	15,258,935
25	Cobalt oxide	Pounds	6,550	3	8,843	6,400	3	8,640
26	Copperas	Short tons	14,897	13,511	104,160	14,118	12,805	69,846
27	Copper sulphate	Pounds	*b*60,000,000	27,215	2,016,000	45,000,000	20,412	1,350,000
28	Chrome ore	Long tons	2,653	2,697	35,125	....	....	....
29	Feldspar	Long tons	18,704	19,003	83,465	22,195	22,550	104,082
30	Fluorspar	Short tons	6,400	5,805	58,304	4,000	3,628	36,440
31	Graphite	Pounds	770,846	349	34,689	392,008	178	17,640
32	Graphite, amorphous	Short tons	165	150	1,252	1,100	998	4,700
33	Gypsum	Short tons	301,536	273,493	910,831	298,572	270,804	974,219
34	Iron ore	Long tons	11,880,000	12,070,080	20,790,000	16,950,000	17,221,200	29,662,500
35	Lime	Bbls., 200 lbs.	*b*56,750,000	5,148,320	28,375,000	*b*60,000,000	5,443,164	30,000,000
36	Magnesite	Short tons	1,370	1,243	7,864	2,200	1,995	14,700
37	Manganese ore	Long tons	11,735	11,924	74,890	14,883	15,121	92,044
38	Mica, ground	Pounds	829,500	377	35,957	750,000	340	31,956
39	Mica, sheet	Pounds	9,900	4	11,103	6,200	3	6,400
40	Mineral wool	Pounds	5,776	5,239	58,936	6,742	6,115	69,481
41	Monazite	Pounds	750,000	340	45,000	1,900,000	862	114,000
42	Natural gas	....	....	....	13,000,000	....	....	12,000,000
43	Paints, mineral	Short tons	47,593	43,167	1,011,182	47,084	42,705	1,086,767
44	Paints, vermilion	Short tons	91	83	111,209	118	107	118,190
45	Paints, white lead	Short tons	87,242	78,155	8,445,174	92,000	83,462	8,740,000
46	Paints, zinc oxide	Short tons	22,814	20,697	1,711,275	22,690	20,498	1,588,300
47	Petroleum (crude)	Bbls., 42 gals.	48,527,336	6,158,119	40,762,962	50,652,025	6,420,742	42,547,701
48	Phosphate rock	Long tons	952,155	967,485	2,856,465	831,498	844,802	2,577,643
49	Marls	Long tons	225,000	228,622	607,500	217,700	221,183	587,790
50	Precious stones	....	....	....	150,000	....	....	150,000
51	Pyrites	Long tons	107,462	109,192	466,466	81,000	82,296	353,560
52	Salt, evaporated	Bbls., 280 lbs.	11,798,659	1,498,193	5,586,326	12,521,498	1,539,178	5,844,348
53	Salt, rock	Bbls., 280 lbs.	2,341,922	297,376	784,063	1,367,638	173,662	518,740
54	Silica, sand and quartz	Long tons	477,670	485,313	418,612	523,640	532,018	553,128
55	Slate, roofing	Squares	611,776	180,474	2,007,321	645,361	190,277	2,062,239
56	Slate, other manufactures	Square feet	4,395,125	12,966	399,758	3,786,599	11,170	369,062
57	Stone, limestone (flux)	Long tons	3,544,398	3,601,459	2,126,636	3,390,000	3,444,240	2,542,500
58	Stone, marble	Cubic feet	6,331,279	518,532	3,576,853	6,942,533	568,593	4,086,261
59	Stone, onyx	Cubic feet	1,450	110	29,000	800	66	10,750
60	Sulphur	Long tons	441	488	7,056	12,000	12,192	192,000
61	Other building stones	....	....	....	*b*30,000,000	....	....	33,000,000
	Total non-metals	....	....	....	378,877,939	....	....	428,266,285
	METALS.							
62	Aluminum	Pounds	817,600	371	490,560	900,000	408	495,000
63	Antimony	Short tons	220	205	39,200	433	393	68,847
64	Copper	Pounds	353,504,314	160,392	33,540,489	386,453,850	175,294	36,944,988
65	Gold	Troy ounces	1,923,619	*c*59,824	39,761,205	2,265,612	*c*70,470	46,830,200
66	Iron, pig	Long tons	6,657,388	6,764,572	71,966,364	9,446,308	9,597,449	108,632,542
67	Lead, value at New York	Short tons	160,867	145,906	10,585,048	156,854	142,298	10,132,768
68	Quicksilver	Flasks, 76½ lbs	30,440	1,056	1,095,840	33,978	1,179	1,313,589
69	Silver, commercial value	Troy ounces	49,846,875	*c*1,550,387	31,403,531	46,331,235	*c*1,441,087	30,254,296
70	Zinc spelter	Short tons	74,004	67,135	5,209,882	81,858	74,245	5,942,890
	Total metals	....	....	....	194,092,119	....	....	240,615,120
	Est. products unspecified	....	....	....	5,500,000	....	....	5,000,000
	Grand total	....	....	....	578,470,058	....	....	673,881,505

(*a*) Bituminous coal includes brown coal and lignite. The anthracite production is the total for Pennsylvania, Arkansas, and Colorado. (*b*) Estimated. (*c*) Kilograms.

ties, and so delicate in texture that instead of steel shavings he called it steel wool. Then by carefully studying the temper and quality of steel best adapted to his needs he was enabled to perfect the product. The advantages claimed for steel wool are that it cuts more quickly and uniformly than sandpaper, does not clog or gum, and being both flexible and perfectly homogeneous, adapts itself readily to the shapes of carvings and mouldings.

TECHNICAL NOTES.

Solders for Glass.—The *Pottery Gazette* describes several metallic solders for glass, proposed by Mr. Chas. Margot. The first is an alloy composed of ninety-five parts of tin and five of zinc, which melts at 200°, and becomes firmly adherent to glass. Moreover, it is unalterable, and possesses a beautiful metallic luster. Another alloy, for the same purpose, is composed of ninety parts of tin and ten of aluminum, melts at 390°, is strongly soldered to glass and is possessed of a very stable brilliancy. With these two alloys it is declared to be possible to solder glass as easily as to solder two pieces of metal. The operation is as follows: The two pieces of glass to be soldered can either be heated in a furnace and their surfaces rubbed with a rod of the solder, when the alloy as it flows can be evenly distributed with a tampon of paper or a strip of aluminum, or an ordinary soldering iron can be used for melting the solder. In either case, it only remains to unite the two pieces of glass and press them strongly against each other, and allow them to cool slowly.

Rustless Casting for Iron and Steel.—A French process for this purpose, described in the *Railway Review*, consists in forming on the metal surfaces a double carbide of hydrogen and iron, which is said to be extremely hard and adhesive. The treatment is effected in a pair of gas retorts, set side by side, and raised to a temperature of from 600° to 700° C. The articles in this case are placed in a retort for about twenty minutes, when a current of hydrogen is turned into the retort and kept on for 45 minutes, a small quantity of naphtha being now introduced, the supply of which is kept on for ten minutes. The naphtha is then shut off, a current of hydrogen is turned on for fifteen minutes longer, when the process is finished. All that remains is to cool the retorts down to 400° C., after which the retort lids may be taken off and the product removed. The coating thus produced has a bluish color, and is stated to be so adherent to the metal that a treated bar can be bent through an angle of 45° without disturbing it.

Electric Tanning.—The *Electrical Review* gives the following brief summary of the improvements in this method suggested by Folsing.

The tanning pit has a capacity of 15,000 liters, and is about 80 inches broad and 10 feet long. Electrodes of nickeled copper are fixed to the longer walls of the pit, and in the latter the hides are so suspended that the current has to pass right through them. A current of 12 ampères with an E. M. F. of 12 volts is used. The tanning matter consists of oak extract, with a little hemlock extract added, both of which are cleared and decolorised by a special electrolytic process. By these means Folsing states that he has succeeded in obtaining good leather in seventy-two hours from light cowhides, in five days from heavy cowhides, and in six days from heavy oxhides.

Solidified Gelatine.—The *Scientific American* gives the following additional details respecting the transformation of gelatine into an insoluble substance, by the action of formic aldehyde, to which several references have been made in these notes, viz.:

Gelatine possesses the curious property of becoming insoluble in contact with formic aldehyde, and, at the same time, of preserving perfect transparency. Gelatine rendered insoluble, or "petrified," to use a more appropriate term, resists water, acids and alkalies. It resembles celluloid, but has the great advantage over the latter of not being inflammable.

The gelatine used is the ordinary article found in commerce. The formic aldehyde is what is commonly called "formol," "formaline" and "tannaline." The commercial product is a 40 per cent. solution of formic aldehyde in water. It is a colorless, syrupy liquid of a pungent odor. The vapor is not inflammable, and it is a powerful antiseptic.

To obtain moulds of statuettes, etc., take 2 pounds of good white gelatine and steep it in a quart of water for a night. The next day the whole is melted over a water bath. For delicate mouldings, the solution is diluted with a little water. The mould, which may be made of plaster, clay, or metal, having been prepared, the formic aldehyde is poured into the melted and slightly cooled gelatine. The whole is well stirred with a wooden spatula to obtain a homogeneous mixture. The latter is then poured into the mould and allowed to cool. After the object is taken from the mould, it is finished by immersing it for a few moments in a concentrated solution of formic aldehyde, or, if it is too large for immersion in the solution, its surface is painted therewith.

Objects obtained with the gelatine alone are transparent and resemble glass. However, by previously adding to the gelatine some finely-sifted zinc white, mixed with a little water and alcohol, and operating in the same way, beautiful imitations of white marble may be obtained.

By mixing the oxide of zinc with appropriate colors, objects of all shades may be obtained, and, by properly arranging the colors, veins, striæ, spots, etc., may likewise be produced. The solidified gelatine may be used for imitating mother-of-pearl, tortoise-shell, amber, coral, etc., and for the manufacture of toys and artificial flowers.

BOOK NOTICES.

A Text-Book on Plain Lettering. By Henry S. Jacoby, Associate Professor of Civil Engineering in Cornell University. First thousand. New York: Engineering News Publishing Company, Tribune Building. 1895.

The author has here endeavored to provide our technical schools with a text-book containing "a detailed treatment of the Roman, Gothic, and some other styles of plain lettering which are suitable for engineering and architectural drawing." The work is illustrated by forty-eight full-page plates, beside numerous illustrations in the text, of which there are eighty-two pages.

The author has taken the Roman alphabet as the basis for his discussion, and has endeavored to reduce spacing to a definite system, using the same scale as in the proportioning of the letters. Chapters I and II treat of the construction and spacing of letters respectively; Chapter III, of titles; Chapter IV, of the selection of styles, and Chapter V, of mechanical aids.

In treating of the lettering on architectural drawings, the author remarks, very truly, that "many of the styles employed in practice approach very nearly to illegibility, including even those on working drawings. Some of them are of such odd, irregular forms, and so utterly devoid of beauty, as to raise the question why they were ever introduced."

The system of round writing, now so extensively in vogue, seems to be entirely unnoticed, either for praise or blame. It cannot be that the author is not familiar with it; it may be that it is not considered as a variety of plain lettering, though it would seem to be at least as nearly legible as the sample of architectural lettering given on page 23, and far more rational and beautiful. T.

Computation Rules and Logarithms, with Tables of Other Useful Functions. By Silas W. Holman, Professor of Physics at the Massachusetts Institute of Technology. New York: Macmillan & Co., and London, 1896.

A surprisingly small part of engineering and scientific computations require to be carried out to more than five places of significant figures. Four and five places suffice for by far the greater part of such work, since they provide for all grades of accuracy up to one-twentieth of one per cent., a limit which is rarely exceeded or required except in special lines of work; indeed, for a large range of engineering work in connection with estimates, specifications and designs of structures, even a slide rule giving but three places of figures is sufficient, and conduces to an enormous saving of time.

But to avoid the really great waste of time and fatigue which attends the use of excessive figures requires the possession of convenient four and five place tables, and a method of deciding at a glance *what number of places is sufficient for the purpose in hand.* While this matter is of the simplest, yet few but expert computers ordinarily possess any mastery of it. In this respect a very large portion of computation work, done not only by students, but by engineers in practice, is not intelligently performed. This small book has been prepared to meet these two requisites. Pages xii–xiv supply rules for places of figures condensed in very simple form, and supplemented by numerical illustrations. The seventy pages of tables contain four and five place logarithms, four and five place log trig functions, four place natural trig functions, four place square roots, reciprocals and slide wire tables and a few important constants. Rules for the use of logarithms, and all the tables and several pages of explanatory matter regarding the rules for significant figures, precede the tables.

Thus the book is by no means a collection of tables, nor does it profess to replace the more extended tables for specially refined work in geodesy, engineering, astronomy or physics; on the contrary, it is chiefly an attempt to enable the engineer and the student to economise labor through intelligent command of the use of figures, and by providing convenient tables supplementary to the common six or seven place tables.

The book will be found of great value to engineers and engineering students, and, if its contents are mastered, will result in considerable saving of time in ordinary numerical computations. G. F. S.

Rope Driving: A Treatise on the Transmission of Power by Means of Fibrous Ropes. By John J. Flather, Ph.B., M.M.E., Professor of Mechanical Engineering, Purdue University. First Edition. New York: John Wiley & Sons. London: Chapman & Hall, Limited. 1895.

If an author desires to meet the requirements of practical men, and at the same time command a large sale for his book, he should confine his treatment to the use of such mathematical characters and methods as practical men can readily understand.

It is not the name of a thing, in whatever language it may be given, that the practical man most wants and has to deal with; *it is the thing itself.*

Elegant expressions and refinements of calculation are all well enough for the school-room and library, but when we come to applied science we want the things that will apply. What a template or gauge is to a workman, so a rule or formula should be to the one who has the work to do. We believe with the elder Trautwine, that, for practical purposes, simplicity and clearness of statement should be the rule, and mystification wholly avoided.

There are many cases in practice which come nearer solving themselves, if given a chance, as, for instance, on page 131, occurs this statement: "Practically it will be impossible to maintain a constant tension in the rope, so that the amount of sag obtained by calculation is liable to vary with the conditions of service;" which, being true, ought to save a deal of mathematical refinement, which is simply useless in these cases. Now we know, from taking a hand at wire-rope driving, that it is as "tricky as a circus mule." The wind, which knows no law, workmanship that cannot be controlled, and momentum and centrifugal force which have their sway, destroy all refinements of calculation, making the appeal to practice absolutely necessary.

The preface gives promise of thoroughness of search and completeness of detail, saying: "The following treatise has been prepared to supply the existing need of a comprehensive manual of practical information concerning rope driving," etc.

Now the practical man has a right to expect what an author says when he puts up such a sign. There is, indeed, much valuable matter in this handy treatise, but close inspection reveals many repetitions of already existing records. We find, for instance, in "Use of Belting," published in 1877, some thirty-four pages of the same detail, and when we come to rope driving—the specialty of this little volume—we find we have a new play of Hamlet with Hamlet left out.

No reader can believe this omission to be a case of justifiable ignorance, nor simply one of inadvertance. Of course, everything cannot be put in a little book, but yet one cannot help thinking that the word "comprehensive" should cover one of the most largely introduced and commercially useful systems of rope driving as that of the American system invented and developed by Mr. Dodge, of Mishawaka, Ind.

About five years ago a committee of the Franklin Institute of Philadelphia, after careful investigation, gave forth its opinion that the system of transmission of power by ropes, invented, patented and introduced by Mr. Wallace H. Dodge, of Mishawaka, Ind., embodies a contribution to practical engineering worthy of special consideration and award, which was given. Now the book before us speaks favorably of certain features of the American, or wound system, to which the committee referred as the invention of Mr. Dodge, notably his slack-taking device, or tightener, patented June 23, 1885, and his improved or double-wind, patented March 22, 1887.

There is no question of the fact that a large number and a great variety of successful power transmissions by the Dodge system are in actual use, of the performance of which there can be but one opinion expressed, and that a favorable one. Considered from the standpoint of practice, therefore, a book on rope transmission of power, is not complete without a full and clear embodiment of the American, or wound system, together with the various details and examples which have been devised and installed by Mr. Dodge.

The author of a treatise, professedly "comprehensive," owes his readers a fulfilment of that promise, and where literature and examples on this subject are abundant, as we know them now to be, there is no excuse for their absence from its pages.

J. H. C.

Modern Copper Smelting. By Edward Dyer Peters, Jr. Seventh edition. Rewritten and greatly enlarged. New York and London: The Scientific Publishing Company. 1896. Price, $5.00.

The present edition of Dr. Peters' "Modern Copper Smelting" is practically a new work. The progress in this branch of metallurgy within the past few years has been so great, and, in certain directions, so radical, as to require that the book should be substantially rewritten. The ground to be covered also is so extensive, and the amount of special information demanded so considerable, that the author has very wisely called to his assistance the services of a number of specialists having intimate knowledge of special branches of the modern science and art of copper smelting. These contributions add greatly to the value of the book, which no one who is interested in the subject can afford to dispense with. Among the special chapters above referred to, is one on the electrolytic refining of copper, a branch of the art which, of late years, has grown to imposing proportions. W.

Modern Stone Cutting and Masonry. With special reference to the making of working drawings. By John S. Siebert, C.E., and Frederic Child Biggin, B.S. New York: John Wiley & Sons. 1896.

The authors treat the subject with special reference to everyday engineering and architectural practice. Chapter I treats of the tools of the mason and stone-cutter, the shape and finish produced by them, the classification of masonry and kindred practical matters pertaining to the handicraft.

Chapter II treats of stone-cutting and masonry proper, and comprises a number of examples of typical engineering and architectural constructions, worked out in more or less detail, with especial reference to the student's needs.

The examples include buttresses, arches, intersecting arches, arch culverts, railroad-bridge masonry, canal-lock masonry, and architectural stonework.

W.

Dont's for Consumptives, or the Scientific Management of Pulmonary Tuberculosis, is the title of a book which, under the authorship of Dr. Charles Wilson Ingraham, is to be issued by the Medical Reporter Publishing Company, of Rochester, N. Y.

The complete work of thirty-five chapters is devoted exclusively to the general management of pulmonary invalids, no reference whatever being made to drug treatments.

The object of the author is to supply the physician with a practical work, and, at the same time, by eliminating technical terms, reduce the text within the easy comprehension of the intelligent patient. The author claims that "a good understanding of his condition is the best remedy for the consumptive." With this book in the hands of his patient, the physician will be relieved of a multitude of details which attach to the successful management of such cases. Special attention has been given those chapters pertaining to the destruction of tubercular infection. W.

Shop Kinks and Machine Shop Chat. A series of over 500 practical paragraphs in familiar language, showing special ways of doing work better, more cheaply and more rapidly than usual. By Robert Grimshaw, M.E., etc. (With 222 engravings.) New York: Norman W. Henley & Co. 1896. Price, $2.50.

To the machinist, whether shop-owner or operative, this collection of ingenious suggestions for saving time and labor will prove a welcome addition to his list of handy reference books, and should prove specially valuable as a guide to be consulted whenever an unexpected difficulty is encountered, or a sudden emergency is to be met. The matter of the book, in fact, is made up largely of ideas that have been conceived and put in practice by a number of the foremost machine establishments, to meet their own requirements, and it covers so great a variety of topics that it is scarcely conceivable that any machinist should not find something in its pages that he could adapt with advantage to his own personal needs.

The book is profusely illustrated and the engravings are unusually well executed. W.

A Pocket-Book of Marine Engineering Rules and Tables. For the use of marine engineers, naval architects, designers, draughtsmen, superintendents, and all engaged in the design and construction of marine machinery, naval and mercantile. By A. E. Seaton, M. Inst. C. E., etc., and H. M. Roanthwaite, M. Inst. M. E., etc. (With diagrams.) London: Charles Grifflin & Co., Limited. New York: O. Van Nostrand Co. 1894.

The *raison d'etrè* of this pocket-book, as set forth by the authors, recites the fact that the existing pocket-books for engineers deal only in a general or incidental way with many matters of the first importance to those engaged in marine engineering, and that much of the meager information thus imparted is so scattered as to be difficult of useful reference, or is obsolete. The authors accordingly have set themselves to the task of preparing a pocket-book of rules, memoranda, tables, etc., especially adapted to the needs of this special class, in which marine engineering questions are dealt with thoroughly. The book appears to be admirably adapted for its intended purpose. W.

REPORT

of a Committee of Judges appointed by the Board of Managers to examine a memoir submitted in competition for the Boyden Premium.

Hall of the Franklin Institute,
Philadelphia, February 29, 1896.

To the Franklin Institute.

Gentlemen:—We, the undersigned, committee of judges, appointed by you to report upon a communication received from the Secretary of the

Franklin Institute in relation to the Boyden Premium, have examined a competitive memoir from a person under the pseudonym of "Massis."

We find that the method suggested in this memoir might be made competent to determine the relative velocities of luminous rays in air, but is not competent to determine the relative velocities of any physical rays other than luminous rays, and, therefore, does not, in our judgment, comply with the terms of the Boyden requirement.

Very respectfully yours,

A. E. KENNELLY,
H. W. SPANGLER,
GEO. F. STRADLING.

Received and adopted at the stated meeting of the Institute, held March 18, 1896.

WM. H. WAHL, *Secretary.*

Franklin Institute.

[*Proceedings of the stated meeting, held Wednesday, April 15, 1896.*]

HALL OF THE FRANKLIN INSTITUTE,
PHILADELPHIA, April 15, 1896.

JOS. M. WILSON, President, in the chair.

Present, 62 members and visitors.

Additions to membership since last month, 19.

The Actuary reported a vacancy in the Board of Managers, caused by the death of Henry Bower, and transmitted, by instruction from the Board, a memoir of the deceased which the Board had adopted. The memoir was accepted and referred for publication.

A special election, held to fill the vacancy thus created in the Board, resulted in the choice of Mr. W. N. Jennings, to fill the unexpired term of the deceased member.

Mr. John H. Cooper read a paper descriptive of the Worthington Self-Cooling Condenser, illustrated with the aid of lantern slides. Discussed by Mr. James Christie, and referred by vote to the Committee on Science and the Arts for investigation and report.

Mr. Cooper also presented a brief *résumé* of certain data of performance of American two-cylinder locomotives.

This subject evoked an interesting discussion, in which Mr. Samuel M. Vauclain, Superintendent of the Baldwin Locomotive Works, Mr. Henry F. Calvin, and the author, participated.

The President then introduced Prof. W. Lascelles-Scott, of London, England, who gave, by invitation, an interesting account of some investigations of the alleged discovery, by Mr. Keeley, of a new force. At the close of his remarks, the meeting passed a vote of thanks to the speaker.

Adjourned. WM. H. WAHL, *Secretary.*

JOURNAL

OF THE

FRANKLIN INSTITUTE

OF THE STATE OF PENNSYLVANIA,

FOR THE PROMOTION OF THE MECHANIC ARTS.

VOL. CXLI. JUNE, 1896. No. 6

THE Franklin Institute is not responsible for the statements and opinions advanced by contributors to the *Journal*.

THE FUTURE OF ELECTRICITY IN RAILROAD WORK.*

By DR. LOUIS DUNCAN.

In a paper read some time ago, I discussed the application of electricity to steam railroad practice, and attempted to define the relations of existing steam railroads to the recent developments in electric traction, and in it all I found no great present hope for the steam roads. The fact exists that there is but a small margin of profit in railroading, and with innumerable electric roads paralleling their steam rivals and absorbing their local traffic, the margin promises to be still smaller. One naturally asks why, if the trolley is less expensive and gives a better service than steam, do not the steam roads adopt the trolley; but it must be remembered that besides local service, the trunk roads have through passengers and freight to transport, and that the three types of traffic cannot be successfully operated on the same tracks, especially if we attempt a really efficient local and express schedule.

---

* A lecture delivered before the Franklin Institute, January 17, 1896.

The question that wants clearing up is this: Is our present method of transportation, as a whole, the result of the characteristics of the steam locomotives that are employed, or is it a natural system which is not greatly affected by the particular tractive power used?

In the United States, the freight traffic is two or three times greater in gross value than the passenger traffic, and, on the whole, it pays much better. A glance at the annual report of any railroad company will also show that, from the point of view of a railroad man, it is a more satisfactory type of traffic. In the first place, the trains being long and running at a comparatively low speed, the resistance per ton is small as compared with passenger trains, which are relatively shorter and run at high speeds. In the second place, the ratio of the paying weight to the total weight of the train is much greater in freight than in passenger service. In an annual report of the Pennsylvania Railroad I find that the average load of freight cars, for several years, is about half the total weight of the train. In passenger service, on the other hand, even on well-patronised roads, the ratio of train weight to weight of passengers is over 50 to 1, and if we take the average conditions, I imagine that 60 or 70 to 1 would not be far wrong.

In freight transportation, where the time is, within limits, of little value, it is easy to calculate what speed will give the best results; that is, what speed will allow us to transport a given tonnage at the least cost. But in passenger traffic the condition of affairs is different, and, with the competition now existing, it is a question not only of cheap transportation, but of quick and comfortable transportation. There is absolutely no doubt that the high speeds used on some of the express trains between New York and Chicago, for instance, or between New York and Washington, are exceedingly expensive. More power is used—for the resistance of the train increases rapidly at the high speeds employed—the wear is increased, both of the train and the track, and expensive and heavy cars are used to give comfortable riding. And yet the railroads are still reducing their schedule time, simply because the public will patronise the road with the fastest service.

With the present steam system, the condition with the three types of service—express, local and freight—is this: express trains are run at comparatively long intervals; local trains are run from or between comparatively crowded centers of population at shorter intervals; and freights are filled in between, partly on regular schedule, partly not. This condition of things fits in very well with the best conditions of economy for steam engines. For a given amount of traffic it is cheapest to use as long trains and as few engines as possible. So steam has this great advantage, that the very conditions that allow local, express and freight traffic on the same tracks also give the best conditions for economy in conducting the traffic. It is only the most crowded roads that have found it necessary to equip four tracks—the four-track roads forming but an exceedingly small percentage of the total mileage.

Now, with electric roads the condition of affairs is very different. As far as the operation of freight is concerned, I will quote what I said in the address mentioned above:

"If we take up the question of freight traffic, the conditions of greatest economy are reached when trains of a maximum weight are hauled by a single locomotive. The tendency in late years has been in the direction of increasing the size of the locomotive, the capacity of the cars and the length of the trains. These changes have necessitated more solid and expensive road-beds, heavier rails and general strengthening of bridges. The outlay has been enormous, but the decreased cost per ton mile for freight transportation has shown the wisdom of the change. On one of the larger roads, which publishes careful yearly statistics, I find that the cost of transportation per ton mile was 1·15 cents in 1870, and ·56 cent in 1890; on another road it was 1·9 cents in 1864, and ·447 cent in 1893. The number of tons per train mile on the first road in 1870 was 103, while in 1890 it was 226 (in 1895 it was 256 tons). In attempting to carry on traffic of this kind by electrical locomotives operated from a central station, we find that we are at a great disadvantage because of the irregular service necessitated by the freight traffic, and the unequal distribution of the load along the line. Suppose, for instance, that there were two stations supplying the line, and that the traffic was uniformly distributed along it; then the capacity of each station would be one-half of the total required capacity. Suppose, however, that the entire traffic was concentrated in one train, then each station would have to have a capacity equal to the total power required for hauling the entire traffic, as the train would first be supplied from one station and then from the other. The line also would have to have a capacity suitable for handling the total traffic. If a number of heavy trains were used, and the traffic was irregular and liable to be congested at one point, as in the case of freight service, then again the capacity of the stations would have to be greater than that required to supply one-half of the normal traffic. If we were to decide to transmit the current to a longer distance, and to supply all the track from one station, using transformer devices along the line, then the capacity of the station itself would only be that required for the normal traffic of the line; but the transformer devices would have to be sufficient to handle the maximum traffic of the section which they supplied, and would have to be given a capacity greatly in excess of their average load in order to supply this energy. We must bear distinctly in mind, in considering the application of electricity to steam roads, that any departure from a uniform distribution of load along the line will increase both the cost of equipment and the cost of operation."

If, then, we operate freight at all by electricity, we must use smaller trains, thus increasing the cost of train attendance and the number and cost of motors, or we must get some cheaper method of distribution, or, finally, we must generate the electricity on the train.

Now, if we increase the number of trains, we increase the enginemen and to some extent the brakemen, and we increase the first cost of, and repairs on, the motors. The increase in these items will depend on the amount of subdivision we attempt. As for the methods of distribution, the only one that would not require an excessive station or transformer capacity would be a high-tension alternating system, with the transformers on the cars. This involves practical difficulties which have not yet been even attacked. As we decrease the size of trains, we decrease the cost of station and line equipment and operation, and increase the cost of train-handling.

As for any self-contained locomotives, we must either use storage batteries, which at present are out of the question, or must have a central station on trucks, as in the case of the Heilman locomotive, which was experimented on in France. We can neglect these either in the present or in the near future.

An ideal local service would consist of a system owning the tracks in the different towns it connects, with cars running through and between the towns. This would give termini measured in square miles instead of square feet, and, with a clear, well-built track, would present an ideal condition of service.

As for ordinary express service, here also, as for local traffic, electricity offers ideal conditions. Trains of one or two cars may be run at short intervals and at high speeds, the conditions of greatest electrical economy and of most satisfactory service being the same. It has often been pointed out that electrical economy demands short intervals and small trains, and, by properly arranging the schedule, the load on the stations may be made practically uniform. It must be taken into account, however, that if we are running trains at, say, 90 miles an hour on a twenty-minute headway, the trains will be 30 miles apart, and at the distances used at present in railroad distribution we would have to provide a larger amount of copper on our lines, that would be used only a short portion of the time.

As for the speeds that may be attained, it is hard to fix a limit. We can get enough power on the train to make 120, or even 150 miles an hour possible, and the small space occupied, as compared with steam engines, would make the air resistance comparatively much less. But we have increased our air resistance per ton by splitting up our trains, and as we increase our speed we greatly increase the power required to drive our train over the line. Still, in passenger service it is not economy solely that sets our speed limit, and I suppose it will finally be limited by the safety and comfort of the passengers. With a perfect roadbed of the present type, and with properly designed motors and cars, 100 miles an hour may be made with comfort and safety.

So much for our electrical service. Its economy for freight is very questionable, and the only advantages it offers are in the smaller trains which are easier to handle and which offer less chance of accident. For local traffic it is ideal. For express traffic it is also ideal within distances of a few hundred miles.

But what are the conditions under which we can carry on this traffic? We certainly cannot run our express trains with either the freights or locals. We would have then to build separate express tracks, and, in order to get the service we have contemplated, they would have to be of the most expensive construction, with no grade crossings or sharp curves. As for running freights and locals on the same track, this may be done under certain conditions.

If we regulate our local service by running it on a regular tramway basis in the towns, and making few if any stops between them, then we may run freights and locals on the same through tracks. But under these conditions we cannot run as the ordinary trolley cars run, stopping at every crossing, because the freights do not stop at all, and their speed is as high as we can comfortably run the light car we would choose for economical town work. It must be remembered, too, that when our local cars are on the same tracks with the comparatively heavy freights, which cannot easily be braked, we cannot take liberties with our schedule; it is too dangerous. If our road has a heavy freight traffic, and we divide the present freight trains into several lighter trains, the tracks will be quite full without the locals, and convenience and safety would point to separate tracks for each.

The above brief survey brings us to the following conclusions: the present custom of using comparatively heavy trains at long intervals is the result of two things—it gives the maximum economy for steam locomotives, and it requires the minimum investment in tracks. If we attempt to accomplish the same service by electricity, we must build at least one extra pair of tracks for express work, and the roads which would require four tracks, because of heavy freight traffic, must increase to six to accommodate the local service. To replace steam by electricity means a greater investment in tracks; it means, with our present prices and methods of distribution, a greater investment in motive power; it promises a cheaper and more satisfactory local and express service, while the freight service may or may not be cheaper, depending on local conditions.

In the paper to which I have referred, I pointed out what I considered the relation of the present steam roads to electricity, taking things as they actually are. I will now consider things as I believe they will or may be, in the not very far distant future. In the first place, local traffic (and I use the word in its popularly-understood sense, not the local traffic of railroad reports) must soon be absorbed by electric lines. The reason is very plain. It is cheaper to transport passengers for short distances by trolley than by steam cars, and the service is much more satisfactory. The ratio of weight of passengers to dead weight is much greater in electric than in steam transportation, and the motive power is cheaper. Cars may be taken almost anywhere and at almost any time, and, for the greater part of the year, it is more pleasant to ride in trolley cars than on a steam road. Besides the ordinary type of local traffic, there is no doubt that populous sections of the country will be networked with electric roads, and that the greater part of the transportation of local freight from outlying districts into cities and towns will be done by electricity. The great advantage of electricity lies in the fact that it does not require skilled labor to run the cars, the machinery—especially if rotary field motors are used—being of ideal simplicity, and requiring very little expense in the way of repairs. Light tracks may be used and the roads will require little grading; for with light traffic it does not pay to increase the permanent investment too much, in order to save running expenses. Every such road should, in fact, represent a special problem, in which the increased running expense for a more expensive road-bed should be balanced against first cost. That such a system is inside the limit of prophecy is shown by the following quotation from a late impression of the New York *Evening Post:*

"Five long suburban electric railways are now in operation, radiating from Cleveland, or will be by early summer. The Cleveland and Painesville line unites this city with the seat of Lake County, and is about 23 miles in length from the eastern city limits. The Akron, Bedford and Cleveland Road has its termini, respectively, in Akron, Summit County, and at the southerly limits of Cleveland, a distance of more than 30 miles. The Cleveland and Berea Company is operating from the southwesterly city limits to Berea, having about 9 miles of single track, exclusive of switches and turn-outs. The Cleveland-Elyria road has just been completed, and extends from the western limits of Cleveland to Elyria, the seat of Lorain County, a distance of over 20 miles; while the Lorain and Cleveland line, which will be ready for traffic in the early summer, connects Lorain, the growing lake port and steel manufacturing town on the lake shore, west of this city, with the westerly limits of Cleveland, and will have about 22 miles of track, exclusive of switches and turn-outs. At present, these lines end at the limits of the city, and depend upon the city electric lines to bring their passengers to the center of the city. No freight has been carried thus far, except small packages. The expectation is, however, to handle a large amount of farm produce in baskets, boxes and barrels, as soon as the proper terminals can be secured in this city. The cars are as large as ordinary railroad coaches, and are combination cars, having apartments for package freight and baggage, as well as passengers.

"Within two weeks, these lines, which are controlled by a syndicate of local capitalists, headed by Mr. Henry A.

Everett, of this city, have united to apply for franchises for 85 miles of road in the streets of this city. They propose to operate these city lines, in conjunction with their suburban roads, as a single great system, and to use the city streets, between the hours of midnight and 5.30 A.M., to bring in milk, fruit and country produce of all sorts. They propose to secure a fine site in the center of the city and erect a large terminal station for the handling of freight, as well as for the accommodation of suburban passengers. This is the first step. Later, as the freight traffic increases, it is expected to construct small freight stations in different sections of the city along the lines of road, in order to supply every section with produce with as little handling and at as small an expense as possible. The roads are all incorporated under the steam railroad laws, and expect to condemn property to connect streets that are not now cut through, thus securing more direct routes than would otherwise be possible; practically, all direct streets radiating from the center of the city being occupied by existing street railroads.

"In order to create a public opinion in favor of this new and radical scheme, the new company offers to give universal transfers, so that a passenger can ride over the whole road for one fare if he desires to, and to sell eight tickets for 25 cents, good for transfers, all hours of the day and night. As the lines they have projected will parallel many now being operated by the two consolidated street railway companies here, the latter have begun a bitter fight, the result of which is difficult to predict. Should the new lines be able to secure the franchise they seek from the city, the old street railway companies threaten to cut their rates of fare to 3 cents, and inaugurate a 'war,' the outcome of which, to all the railway interests involved, could hardly fail to be disastrous.

"The great question involved in the entire matter, however, is the proposed use of the streets, on a large scale, by electric traction companies for carrying freight. If the plans outlined are put in practice, there is a very strong prospect that the new company will undertake to haul freight from one quarter of the city to another, as well as to handle produce and package freight from the suburban districts. Many large manufacturing establishments are directly along the proposed routes, and interchanges of products between many of them are frequent, and involve heavy expense for cartage. The projectors of the new lines believe that, within a few years, they will be able to do much of this business at a saving to the manufacturers, and still realise a good profit on the business. Meanwhile, the great question is the wisdom of allowing a company of this character the unrestricted use of the streets during certain hours, and the ultimate effects of the plan if it is carried out, as it will be, unless the existing street railway companies succeed in defeating the project in the City Council. The general opinion seems to be that the innovation would reduce the cost of placing fruit and farm produce in the hands of the city consumer, and thus be a public benefit, and it is already demonstrated that the electric lines can compete with steam very successfully. The Akron, Bedford and Cleveland Company has been operating cars between Akron and Cleveland less than four months, but it has already made such inroads into the business of the steam railroads, that the Cleveland, Akron and Columbus Railroad Company has laid off two of its way trains between these points, and the outlook is for the development of a good business by the new company. Its time is somewhat longer than that of the steam roads; but the freedom from dust, cinders and similar annoyances of the steam road, and the greater frequency of trains—cars being run on a forty-five minute schedule—seem fully to offset this objection."

With the methods of distribution in common use, such a system could be run for a radius of 10 miles from a single station, and in the next two or three years we may hope to extend our radius at least 20 miles. The agitation for good country roads that is now being carried on may be too late, for, by the time it is really decided to build them, we may have reached an era of electric lines and bicycle paths rendering them unnecessary.

FREIGHT AND EXPRESS FEEDERS.

Express traffic by electricity demands a large investment, a considerable running expense, and a distinct advance over our present methods of electric traction. We can look for revenue only to passenger traffic, with some additional receipts from express and mail. If we take the receipts on steam railroads as a basis, we will find that there are few such express lines that will pay. But we must take into account the great increase in passenger traffic that would follow the quicker service and shorter intervals that would be employed. No one can doubt that, if the time from Philadelphia to New York could be reduced to one hour, and if trains ran every fifteen or twenty minutes, the number of passengers between these two points would be greatly increased. The number of schemes that have been proposed for lines running from Philadelphia, and even from Washington, to New York, shows that the matter is in the air, and is being seriously considered by responsible people. There is nothing "wildcat" about the matter, but one must not blind himself to the practical difficulties that will be encountered. As far as the present steam roads are concerned, it is doubtful whether the increased earnings that would follow the building and equipment of such an electric road would pay them for the great expense of it. They would be driven to it only if an independent line threatened to destroy their through passenger traffic between these points. The existing roads, with their rights of way and terminal facilities already secured, could establish such a service at a much less expense than any independent company. To build a line from Washington to New York, against the opposition of the steam roads operating between these points, would require great ability and shrewdness on the part of the officials of the company, and an enormous outlay of money. No one who has not looked into the subject can imagine the difficulties and expense incident to securing terminal facilities in the different towns; and the cost and trouble in securing rights of way—always considerable—can be greatly increased by the organised and intelligent opposition of companies backed by enormous wealth and influence, and with an experience extending from the introduction of railroads.

Of our ability to run trains at speeds up to 100 miles an hour I have already spoken. Our experience is this: the speed of ordinary trolley cars has been gradually increased in suburban service, until, in certain cases, speeds up to 40 miles an hour are employed. More than this, on the Columbia and Maryland Railroad, which is now being built between Baltimore and Washington, speeds of 60 miles are to be used. In the past year, trains on the Nantasket Beach branch of the New York and New Hampshire Road have been run at speeds above 60 miles, and similar results have been obtained on the Mt. Holly branch of the Pennsylvania Road. In the last two cases, the cars used were not specially constructed for very high speeds, and yet there seemed to be no trouble in operating them. Some of the difficulties that have been feared have proved to be imaginary; some have been overcome; and I suppose that the same will be the case when we attempt the greater velocities demanded by an electric express system. Some years ago, it was supposed that the increase in train resistance at very high speeds would render them prohibitive; but some of the recent runs on steam roads, together with actual experiments made on electric cars at speeds up to 120 miles an hour, have shown that the formulæ that were assumed to be true were wrong, all of them giving too great resistance at high speeds. The work done on resistance by Mr. Crosby is especially interesting. He experimented in two ways. First, he ran a small electric car on a circular track and measured the velocity and the power consumed. From these data, knowing the constants of the motors, he was able to obtain the total resistance at the different speeds used. But he went further than this. He made the front end of the car movable, working in guides against the calibrated spring, and, by getting a record of the movement of the end on a revolving cylinder by a pencil, he obtained the air resistance. Subtracting this from the total, the remainder was the track resistance. These experiments were repeated with heads of different forms, and the effect of the shape on the resistance was determined. The results were checked by placing a model in a rotating frame, and finding the air resistance at different velocities. The results of Mr. Crosby's work showed that speeds as high as 120 or 150 miles could be made without increasing the power to an impossible (?) amount, provided we make the train of a proper shape. The form of our electric machinery allows us to dispose our weights near the track, and so allow higher speeds to be safely used than could be allowed with the present type of equipment. The rotary motion of the armatures is much more advantageous than the reciprocating motion of the piston, and the wear on track and bridges would be much less.

Up to the present, rotary field alternating motors have been used only experimentally, but the experiments have been most promising, and the characteristics of the machines fit singularly well the requirements of the traffic we have been considering. Such motors are most efficient for the constant speeds, while their construction and regulation are of ideal simplicity. Besides this, the multiphase alternating system is peculiarly adapted to long-distance transmission. The great plant at Niagara, which is in successful operation, and from which it is proposed to transmit power over long-distances, is a multiphase plant. The system allows us to use any voltage we wish on the line, and the problem which has not yet been attacked—the collecting of the current at these speeds—is helped by this fact.

The first road that will, to a certain extent, fulfill the conditions of an electric express road is now being built between Baltimore and Washington, and its operation will solve many of the questions which come up, in the higher speed work we are considering—questions such as the type of car that may be used, the mounting of the motors, etc.

It is only between crowded centers of population that such roads can be made to pay. Between Washington and New York, New York and Boston, and possibly between New York and Chicago, they might be constructed at present; but, as the distances increase, the demand for the comforts of trains like our "Chicago Limited" work against our condition of light trains. On long trips we are accustomed to dining and sleeping cars, to observation and smoking cars, and we cannot provide all these on our electric train run at 100 or 120 miles an hour. Still, we might combine enough of these comforts in a single train to make an eight- or nine-hour trip to Chicago not unpleasant, and that is the greatest distance I have in mind as a requirement of the immediate future.

As for the safety of such a service, it should be greater than with our present system. With a perfectly clear track for our express trains, with lighter weights allowing quicker braking, with simple machinery that permits a low center of gravity, with less strain on our road-bed due to the rotary motion employed, with a perfect track construction and the definite block system that electricity permits, the service should be absolutely safe. The comfort of the passengers would depend on the construction of the track and of the cars. We know that we can build a smooth track, and we may depend on the ingenuity of our car builders to give us smooth-riding cars.

Such a system offers us a service at once frequent, rapid, comfortable and safe, surpassing the present steam service in each of these particulars, and there is no problem involved which our present knowledge of electric traction and transmission will not enable us to solve successfully.

But the local and express services on the lines I have sketched out would be entirely different. They could not be operated on the same tracks, the types of cars and motors would not be the same; even the methods of distribution would, in all probability, vary. The local service, extending in every direction that offers a profitable passenger or freight traffic, would employ a cheap and comparatively light road-bed, open passenger cars for summer and the ordinary closed cars for winter use. The express trains would be vestibuled, the cars presenting a smooth surface, and the locomotives designed to give the least possible air resistance. The tracks would be heavily built, straight, with no grade crossings—more expensive even than the present steam roadway. On steam roads, one cannot at a glance distinguish between local and express trains. The types, both of locomotives and cars are similar, the fact that both services use the same tracks demanding powerful locomotives for both services. Where the stops are numerous, the power required to accelerate the heavy trains used demands locomotives as heavy as those which give the sustained power for the express trains. We can, and, often do, change cars from locals to express trains, and but for minor differences in design, we could use our locomotives indiscriminately for either service. In our electrical system, the difference between locals and express would be obvious. We could not use either our local cars or motors for express service, and our express trains would be hardly more at home on local tracks.

As for freight service, I own that my ideas on the subject are not as clear as I could wish. The remarkable efficiency and cheapness of the present system make the problem of improvement a difficult one. As I have said before, the present methods of distribution demand shorter trains, and there is nothing I can see in the immediate future that promises to change this condition. With our electric trains we have some very important advantages, such as less fuel, cheaper switching, cheaper engineers, less repairs on engines and cars, smaller cost of maintenance of way. Against these items we have the increased cost of service due to the smaller train units employed. In any case, whether we use steam or electricity, our freight lines would be through lines. From points along them electric roads would radiate, draining the surrounding country and feeding the main line. Most of the trunk lines in the country have been forced to build or buy branch lines to act as feeders, and these branches rarely pay their operating expenses. Electricity will, in many cases, change this, and will both decrease the expenses and increase the traffic on the branch roads, and so directly benefit the main stem.

The invention and development of the steam engine led to the concentration of industries. The maximum economy is reached in the use of large units, of great factories of concentrated effort. This has had its evil side, socially, morally and often industrially. Electricity lends itself to the distribution of power, to the economical use of small units, and we are already beginning to feel its effect. In many cases it puts the small manufacturer nearer the level of the larger corporation; it is to-day distributing the crowded population of great cities to the surrounding suburbs. Its moral and social effects are far-reaching and wholesome, tending, as they do, toward greater individuality with its accompanying greater independence.

And to a certain extent this is true with respect to electric railroads. The substitution of electricity for steam demands small units, and it sharply differentiates the three types of traffic, local, express and freight. Local roads will network the country, carrying passengers and freight to cities and towns, or to through freight and express roads. Express lines will be built between large cities, the equipment of track and trains differing radically from that for local service, and speeds of from 100 to 120 miles will be attained with comfort and safety. The freight service proper will be done on through tracks fed from local lines, the type of equipment differing widely from that for either local or express service.

I have not considered how all this is going to come about. It means, of course, a radical change not only in the system of motive power, but also in the roadway of some 200,000 miles of railroad. The cost of it would run up in the thousands of millions of dollars. But this is certain, if the transportation work of the country can be carried on more cheaply and efficiently by electricity than by steam, then it is only a question of time when electricity will be substituted. We already have an example of the future type of local traffic in the roads spoken of in the New York *Evening Post.* Express traffic has been fairly well represented by the Baltimore-Washington road. Through freight is the one doubtful point, but we regard it with the eyes of hope.

There are, I hope, but few of us here who will not see a comprehensive adoption of electricity on some of our great systems, and there are some who will live to see the time when the steam locomotive will be considered a curiosity.

THE FRANKLIN INSTITUTE.

Stated Meeting, April 15, 1896.

MR. JOS. M. WILSON, President, in the chair.

THE WORTHINGTON COOLING TOWER FOR THE CONTINUOUS USE OF CONDENSING WATER.

BY JOHN H. COOPER.

The chief object of this apparatus is to reduce the temperature of water, which has become heated in some previous operation, in order that it may be used over and over again for the same purpose. In cities, where even the feed-water for steam boilers is obtained only at considerable cost, the purchase of water for condensing purposes, requiring about twenty-five times the amount of water in the steam, is commercially impracticable, for the reason that its cost will be greater than the advantages gained.

The cooling of warm water, therefore, and re-using it for the condensation of steam in the steam engine, for increasing its power without additional fuel, or for maintaining the same power on less fuel, become matters of great commercial importance, because this use of water is almost without cost. Furthermore, as is well known, there are even disadvantages attending a natural water supply, such as the cost of piping and pumping, obstructions to pipes, valves and water passages, gritty and corrosive matters, which are detrimental to pump and pipe interiors and to working parts, and the inconveniences of floods and drought, over which we have no control.

Any invention, therefore, that removes the difficulty and cost of obtaining water for condensing purposes, in localities where natural supply does not exist, or fails at times, must have great commercial value. If it were possible to construct steam motors and run them condensing, with all the advantages secured by this system, by the use of no more water than that employed for making their steam, a great gain would be effected in steam economy, and nothing henceforth would be in the way of locating them wherever desired. The Worthington "cooling tower" enables steam-power users to avail themselves effectually of this advantage.*

This apparatus comprises several specially designed mechanisms for cooling a certain quantity of water and using the same over and over again. It embodies the results of much experimentation, conducted for some time in the establishment of Henry R. Worthington, in Brooklyn, N. Y., by which are secured all the requirements for cooling water with continued good results, combined with durability of mechanism. Its distribution and disintegration of water, to effect intimate contact and commingling with atmospheric air, are complete, while the space occupied by the apparatus is reduced to the least amount compatible with the work to be done.

It is now offered to engineers and steam users in a practical form, as the finished result of trials in actual service in connection with several large power plants in New York City and elsewhere, after having successfully passed the ordeal of experiment.

Owing to several meritorious features, the cost of producing a vacuum by this novel system is but slightly greater than that of the ordinary condensing apparatus operated with a natural and abundant water supply. As the heat of the exhaust steam from the condenser pump is transferred to the feed-water and returned to the boiler by means of a suitable heater, it is practically all conserved. The power to operate the fan is quite insignificant, and, in fact, the total expenditure to run the Worthington "self-cooling condenser," when deducted from the great gain afforded the main engines by the vacuum, results in an economy that gives a handsome return on the investment, and places a plant equipped with it, nearly, if not fully, on a par in efficiency with the best and most recent practice of condensing engines.

---

* The apparatus herein referred to is manufactured by Henry R. Worthington, Brooklyn, N. Y.

An important advantage is gained in the use of this apparatus, in that no vacuum is required to be maintained in

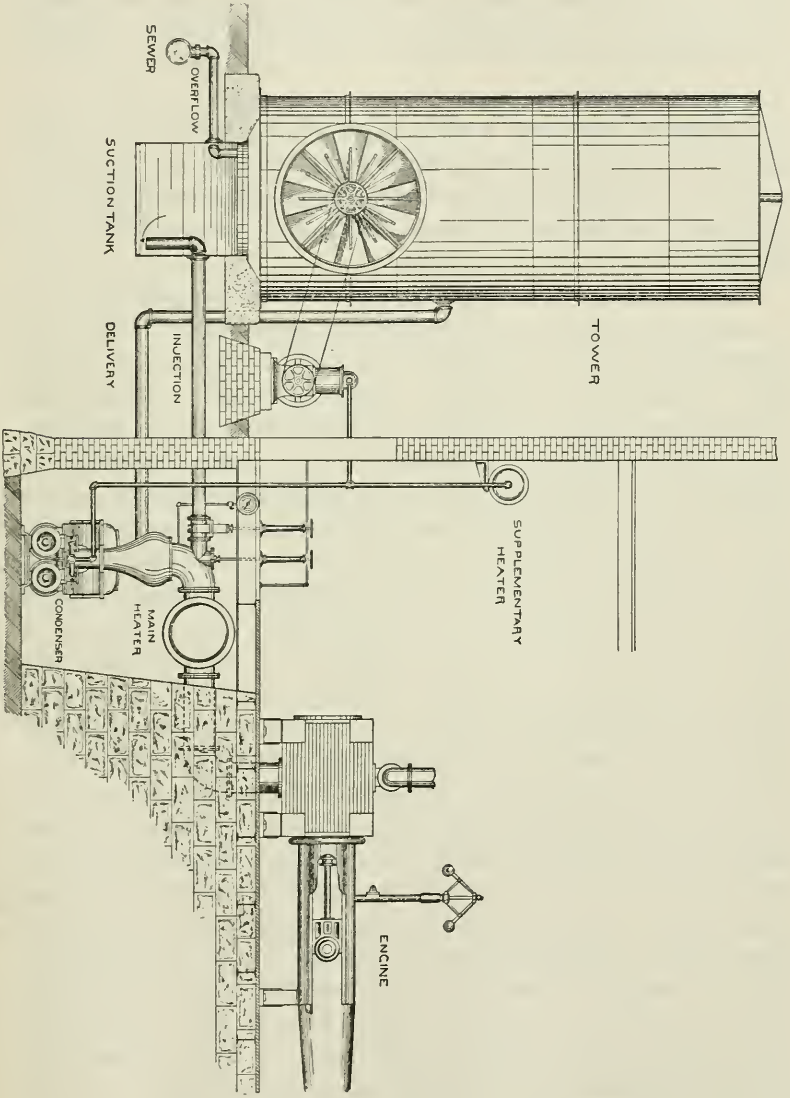


FIG. 1.—Worthington self-cooling condenser (showing tower in yard).

the tower, nor in its water connections with the condenser pump, and that the tower may be placed at any reasonable distance from the engine, as, for example, in the open air or on the ground, or upon the roof of some adjacent building. With this system, the exhaust pipe between the steam cylinder and the condenser vessel (which pipe in most cases is very short) is the only part required to hold a vacuum, thus effecting a marked economy in construction and maintenance over others.

In order to present a clear idea of the size of a cooling tower for a given horse-power, of the quantity of water for starting the apparatus, and of the general results to be expected from its performance, the following particulars are offered:

Under ordinary circumstances, for condensing the steam of a 1,000 horse-power engine, using say 20 pounds of steam per horse-power per hour, a tower 17 feet diameter by 31 feet high is ample. The condenser pump circulates 1,500 gallons of water per minute; the fan is 9 feet diameter, and requires 3 per cent. of the total power of the engine to drive it. Starting the apparatus with 2,800 gallons of water in the tower-tank and adding no more to it, except that given by the condensed steam, there will be no cost for condensing water during all running time thereafter, during which there will be produced and maintained in the condenser, a good vacuum, resulting in an economy of 20 to 30 per cent. of the fuel used to make the steam for power. A vacuum of 22 inches is guaranteed, while 25 to 26½ inches are realised in practice even during the summer months. It will thus be seen that, after once filling the suction or subsiding tank, no more water need be supplied to the apparatus other than that fed to the boilers, which, when condensed after its use for power as steam, makes up entirely the loss of water by evaporation in and at the top of the tower. During cold weather when more cooling is done by contact, there is an accumulation of water in the tank which escapes by an overflow pipe, and which may be arranged also to carry away the grease from the cylinder lubrication, which is constantly being carried over by the water of condensation.

The condenser pump delivers the warm water to the top of the tower where it is distributed evenly over the entire area of the cellular arrangement within the same. As the water falls through the tower, it is repeatedly divided and subdivided into drops and streams during its downward course, meeting, throughout its whole descent an upward current of air, impelled by the fan which is constantly in motion at its base.

It will be apparent, therefore, that, with the unchanging nature of the cellular devices, which are of earthen tile, and with the uniform disintegration of the falling water and its thorough contact with atmospheric air, the greatest number of heat units, within a given space, are abstracted from the water and carried away by evaporation into the atmosphere above the tower.

"The effectiveness of the tower as a cooling apparatus depends upon the capacity of atmospheric air to absorb and carry off heat and moisture. Broadly considered, the air becomes the condensing medium in the place of cold water as ordinarily employed, and on account of its general distribution the process is not limited as to locality. The specific heat of air is 0·238. If we depended upon the direct absorption of heat by rise in temperature we should have to raise about 4 pounds or about 55 cubic feet of air 1°, or 1 cubic foot 55°, to absorb a heat unit, 1,000 cubic feet 55° to condense 1 pound of steam, and from 15,000 to 20,000 cubic feet per hour to condense the steam used per horse-power hour. This would be the requirement if the air were circulated over the surface of pipes containing the steam as water is circulated in a surface condenser. But when air is brought into direct contact with water there is a cooling action due to evaporation, much more extensive than that due to the elevation of temperature. If you wet your hand and hold it in a current of air, you at once experience a sensation of cold. The water is being absorbed or evaporated by the air, and is taking from your hand and the surrounding objects the latent heat of evaporation. When a pound of water is evaporated in this way five times as much heat disappears as when a pound of water is raised from the freezing to the boiling point, and every pound of water so evaporated absorbs heat enough to condense a pound of steam. By passing, therefore, a current of air over a body of water favorably disposed to be acted upon and absorbed by the air, we can, by the evaporation of a portion of that water, absorb and carry off in the air current a large amount of heat, and cool the water sufficiently to allow it to be used again for injection purposes. Further, for every pound of water thus carried off by the air, enough cold is generated (if the unscientific expression may be allowed) to condense a pound of steam, so that there is no diminution of water in the system, and the only water required to be supplied continuously is that fed to the boilers, *which is less, of course, than if the plant were run non-condensing*, on account of the reduced steam consumption of the engine. The system, therefore, allows a plant which must even buy its feed water, to run condensing with a less expense for water than when exhausting into the atmosphere.

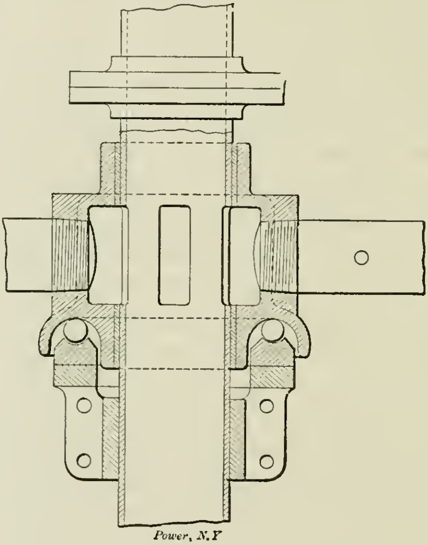


FIG. 2.—Details of revolving distributor.

"The details of the system are apparent from the engravings. The hot water from the condenser pump is delivered through the revolving distributor into the top of the large tank. This distributor is an interesting detail. It is necessary that the water shall be evenly distributed through the tower section, in order that the maximum effect may be derived from a given quantity of air. Several forms of perforated plates were used as distributors, with the result that the water was forced either to the center or outside of the column and the air found clear passages. The distributing pipe is mounted at its center on ball bearings, as shown in the detail drawing, *Fig. 2*, also in plan on *Fig. 4*, and, rotating like the ordinary lawn-sprinkler under the reaction of the issuing jets, distributes the water uniformly over the cross section of the tower. The first impression is that the issuing jets would be thrown to the outside and impinge on the walls of the tower, but the actual effect is that the drops fall vertically, forming circles as they issue from the pipe, and effecting a very uniform and satisfactory distribution. The body of the tower is filled with short lengths of cylindrical tiling over which the water trickles, meeting the ascending current of air induced by the fan as shown. The tiles are so arranged as to break joints (see *Fig. 3*, also *Fig. 4*), and present a generous surface over which the water spreads in a thin sheet in the best possible form to be acted upon by the air, which is passing through the interstices of the tiling, and being constantly deflected and broken up into small columns in intimate contact with the wetted surfaces. At the bottom of the tower the water collects in a tank, whence the supply for the injection is taken. Mingling in the condenser with the steam, and being heated by its condensation, it is again delivered by the pump to the cooling tower, increased in quantity by the steam which it has condensed and which is sufficient to replace that lost by evaporation. There is constantly coming into the system the water which is drawn from the city mains or other source to feed the boilers. There is constantly going out

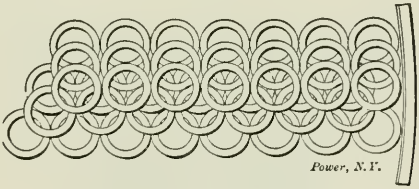


FIG. 3.—Showing arrangement of tiles.

of the system the water evaporated in the cooling tower, an amount which can no more than equal, and may be considerably less than, the steam condensed; for, in addition to the evaporation, we have the cooling effects of radiation from the surface of the tower and the connecting pipes, and the rise in temperature of the air in passing through the tower which it leaves, it is to be noted, at the hottest end, and these last processes condense steam without the loss of water.

"If, to start with, a few gallons of water be placed in the suction tank, the system will operate without attention, and all loss of water by evaporation and slight leakages will be provided for. There will be just enough accumulation of circulating water to cause a slight overflow that will carry off the oil and grease from the engine that come over with the exhaust steam, and which would tend to accumulate in the suction tank.

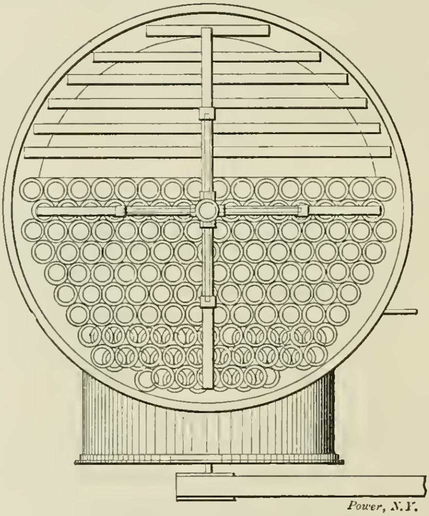


FIG. 4.—Showing plan view of tower.

"In the application of this apparatus to a plant operating non-condensing, no change will be made in the method of feed-water supply, as ordinarily employed. The ordinary heater is left in position, and the exhaust steam from the engine passed through it on the way to the condenser. The exhaust of the condenser pump and the small engine which runs the fan (if a separate engine be used) is passed through a supplementary heater and condensed by the absorption of its heat by the feed-water, which has already been heated to the temperature of the exhaust steam, say 120° to 130°, by the main heater between the engine and the condenser.

"The temperature of the feed-water, after passing the supplementary heater, will approximate 180° to 190° F. This enables the boilers to operate under specially good conditions for condensing engines.

"When the cold city water for the boiler-feed is passed through the main heater, it acts on the passing steam as in a surface condenser, reducing the work of the condenser proper and the amount of injection required. The power required to run the fan is procured very cheaply, as the heat which passes through the engine is, in great part, returned to the boilers in the feed-water.

"By the use of this system, any plant, wherever located, can secure all the benefits accruing from condensation, and with very nearly the ultimate economy attainable with a plentiful supply of condensing water. Even a plant in a city building can be run to advantage in this way, by placing the cooling tower on the roof and using a surface condenser in the basement of the building, where also the motive and other machinery is placed. The descending column of circulating water balances the ascending column, and the hydrostatic head pumped against is no greater than though the tower were upon a lower level. There will, of course, be the friction of the greater length of pipes to overcome, but this can be greatly reduced by making the pipes of sufficient size to keep the velocity down. Where the only water available is so charged with lime or other impurities as to be undesirable for boiler purposes, a surface condenser can be installed, and the condensed steam used over and over continuously in the boilers. In this case, the water lost by evaporation in the tower is made up automatically by delivering the available water to the suction tank below the cooler, as required. In no case will this be more than would be required if the engine were run non-condensing, and the practical advantage of soft, pure feed-water is obtained in addition to the economical advantages of the condensing engine. Another practical advantage, especially in metropolitan plants, is the absence of noise and vibration, due to the exhaust and greasy discharge from the exhaust pipe.

"There is yet another important point worth noticing. The apparatus is able to maintain as high a vacuum in the summer as in the winter; for, while in hot weather it receives less help from direct radiation, or the effect of contact with cold air, the evaporation becomes a much more important factor, because the warm air is more effective in absorbing moisture, evaporation proceeds at a much greater rate, and is consequently many times more effective in cooling."

The Worthington Cooling Tower Applied to Ice-making and Refrigerating Apparatus.—The cooling tower portion of the apparatus described above has, independently, varied and important uses, the most important of which is the cooling of water that has passed over ammonia coils in connection with ice-making or refrigerating machinery, and has thereby become heated. After leaving the cooling tower the water can be used again on the coils without any further demand upon the water supply, be it from wells or the city mains, except to make up that which is lost out of the tower by evaporation. This feature will appeal to the managers of cold-storage plants and breweries as a thoroughly desirable result, especially when city water has to be purchased at great expense during the hot summer months.

Fig. 5 is taken from a photograph of a Worthington cooling tower that has been in operation during the heated term of last summer, in a cold-storage plant. The tower, as will plainly be seen, is supported over the ammonia coils upon a a light framework, and the fan is driven by a belt from the main shafting. The heated water from the coils flows to a circulating pump located in the engine-room, and it is then delivered to the top of the tower, cooled and allowed to again flow over the coils of the condenser. The application of the apparatus to this particular plant resulted in the saving of seven-eighths of the cost of water for cooling purposes; that is, in fact, it reduced a yearly water bill of

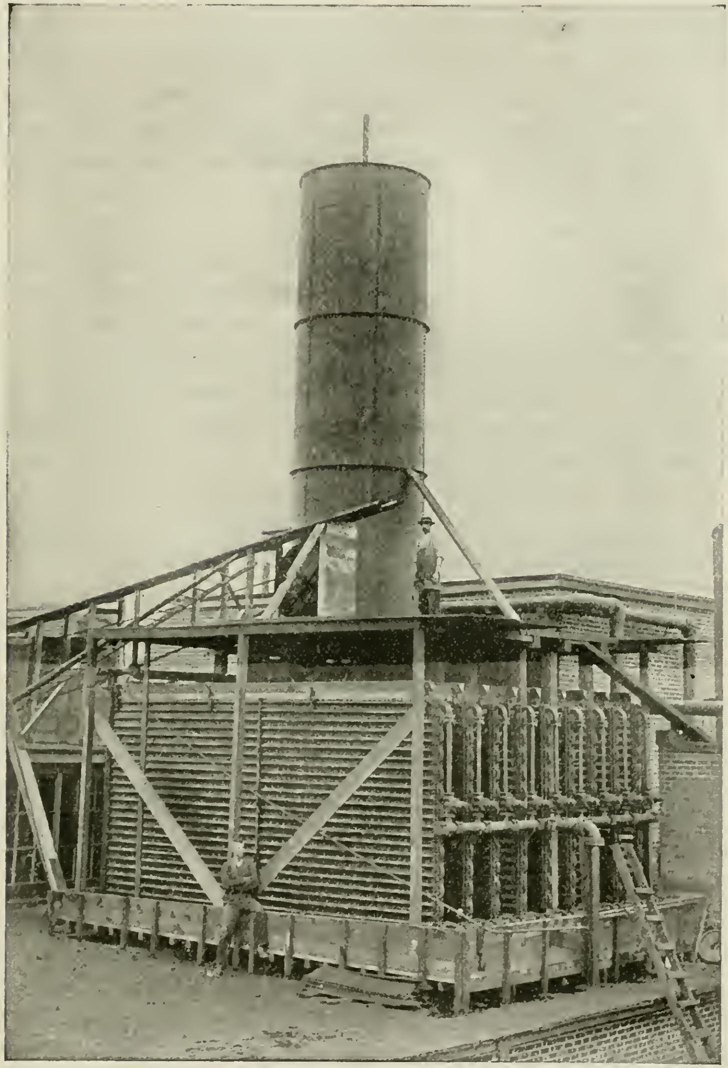


Fig. 5.—Worthington cooling tower in connection with ammonia condensers.

$4,000 to $500, thereby realising an economy that fully paid for the cooling tower in a few months.

It may be added that, when a line of shafting is not convenient, a small self-contained engine is used with equal advantage; and that, when the situation is favorable, the tower can just as well be placed beside or under the coils.

It is obvious that this system of cooling water is decidedly preferable to the use of salt or calcareous well water, as all the extra cost of pumping the same, and the trouble experienced from the corrosive action or the deposition of lime and magnesia on the coils, which so materially reduces their efficiency, is remedied.

Another field of application, and one which has not as yet received the attention it deserves, is the cooling of water for use on bearings of rolls or engines, or for cooling the tuyeres, the jackets and other parts of blast furnaces and smelters. In fact, the Worthington "cooling tower" can be applied in any process or manufacture where it is desired to remove heat by running water.

ENGINEERING AS EXHIBITED ON THE GREAT LAKES.*

BY JOHN BIRKINBINE,
Member of the Institute, Past President Am.I.M.E., etc.

Standing at the stern of one of the lake passenger steamers, shortly after it had started on its eastward course of 390 miles across Lake Superior, and looking back at the long array of receding electric lights, which indicated the location of Duluth and her sister city, Superior, one is impressed by the thought that less than a quarter of a century had transformed a sarcastic reference on the floor of the House of Representatives at Washington to the "Zenith City of the Unsalted Seas" into a reality. The view of these important and rapidly growing cities was magnificent, as the vessel sped over the great inland sea of Superior, whose water surface exceeds 30,000 square miles, for the illumination extended along the lake shore fully 15 miles, and the lights shone on the hillside to a height of 200 feet or more above the lake. Near the center of the space illumined was a concentration of brilliancy created by a raking view of numerous arc lights on an iron-ore shipping dock, one-half mile in length, and the effect as seen from the water was heightened by the two ruby lights, one fixed, the other revolving, which the Government maintains to direct vessels into the safe harbor of Superior Bay, through the narrow, artificial canal, which divides Minnesota Point.

---

* A lecture delivered before the Franklin Institute, December 6, 1895. The lecture was liberally illustrated by a large number of lantern slides.

A knowledge, gained from repeated professional visits covering parts of two decades, of how Duluth has grown, and how the entire territory tributary to the Great Lakes has advanced, credits much of this progress to the engineer; and a recapitulation of his achievements in the lake district, would, of itself, occupy an evening, while there are a number, which, if described in detail, would each merit the entire time allotted to me. With so much to choose from, works of magnitude must be slighted which may appear of greater importance than others which are mentioned; hence, no claim for completeness is presented, but an attempt will be made to illustrate the importance of the Great Lakes, and chronicle some of the advances which have contributed to their present development.

But little attention can be devoted to the lowest of the lakes, Ontario, although it has numerous important works of interest to engineers, and the lecture will merely cover some of the impressive features in journeys between Buffalo and Chicago or Duluth.

DIMENSIONS OF THE GREAT LAKES.

These bodies of water are truly "Great Lakes," and great engineering achievements are associated with them. Few realise that the bulk of the immense traffic of the Great Lakes (a traffic in volume in advance of any navigation with which we are familiar in Philadelphia) is carried on at levels of from 573 to 602 feet above tide, and that the 3,000 craft which form the lake marine west of Buffalo float at heights of from 10 feet above to 19 below the crown of the hat of the statue of William Penn on the top of the

Philadelphia City Hall. We are familiar with the expression "Great Lakes," but do not appreciate their magnitude.

If Lake Superior be superposed on Pennsylvania and adjoining States, its eastern extremity (Whitefish Bay) can be placed at Sandy Hook, N. J., and Duluth at its western end would be found beyond Wheeling, W. Va., the greatest width of the lake corresponding closely with the north and south boundaries of Pennsylvania.

If Lake Michigan be so placed that Philadelphia occupies the same relative position on its shore as Chicago, the northern end of the lake would extend to Montpelier, Vt., its width being practically the distance between the cities of Philadelphia and New York. Treating Lake Huron in a similar manner, and placing its southern extremity at Philadelphia, it would extend in a northern direction beyond Albany and Troy, N. Y., the foot of Georgian Bay corresponding with New Haven, Conn., that of Saginaw Bay being at Pottsville, Pa., while the Straits of Mackinac would approach Rochester, N. Y., the distance from the foot of the lake to the straits being practically that between Philadelphia and Pittsburgh. Assuming Philadelphia as occupying the same position on the shore of Lake Erie as Buffalo, Pittsburgh would correspond with the mouth of the Detroit River, and the distance across Lake Ontario from Watertown, N. Y., on the east, to Hamilton, Ont., on the west, is equal to that from Philadelphia to Cumberland, Md.

Starting at Duluth, a vessel of moderate size would, at present, after traversing 1,300 miles, passing *en route* the Sault Ste. Marie, the Welland and the St. Lawrence Canals, practically reach tide level at Montreal (which is 25 feet above the sea), and still be nearly 1,000 miles from the Atlantic Ocean.

Lake Superior, as above indicated, is 602 feet above tide, and is, therefore, the highest as well as the largest and deepest of the lakes; in fact, it is the largest known body of fresh water, its maximum depth being 978 feet; the bottom is nearly 400 feet below ocean level, and at ocean level its area would be between 10,000 and 15,000 square miles. But Lake Superior is not alone in this particular, for Lake Michigan and Lake Huron, whose surfaces are 581 feet above the ocean, have maximum depths of 870 and 702 feet respectively, and Lake Ontario, 247 feet above tide, is 678 feet deep.

The waters of Lake Superior reach the level of Lakes Huron and Michigan through the St. Mary River, where about 90,000 cubic feet of water per second dash over the rapids. To overcome this difference in elevation (18 feet), locks have been constructed at the Sault Ste. Marie, in connection with a canal about 1 mile long, of which mention will be made later.

LAKE SUPERIOR.

In considering some of the prominent engineering features of Lake Superior, it is well to remember that the contiguous territory was practically an unbroken wilderness with only a few trading posts scattered along the lake shore, but little more than half a century ago. Although the discovery of mining tools in ancient workings show that the Indians had mined copper in the Keweenaw Peninsula of Michigan, and some little work was done in the latter part of the eighteenth century by whites, no mining of copper or other minerals was attempted in a business way until 1845. Now there is an enormous mining industry from which up to date 100,000,000 gross tons of iron ore, 800,000 tons of metallic copper, considerable silver, nickel and some gold, have been extracted and marketed.

Copper Mining.—In no part of the world has the engineer done better work than in the Lake Superior iron and copper regions. The depth to which the workings have been carried, and the expense of fuel, encourage, at some of the mines, the most elaborate and economical machinery. The plant at the workings of the Calumet and Hecla Company is unexcelled in its equipment. This company now has a vertical shaft 4,700 feet; and a neighboring mine, the Tamarack, has two vertical shafts, each 4,450 feet deep. These shafts being located at an elevation of 650 feet above Lake Superior, extend far below the bottom of that lake, and, in fact, nearly three-quarters of a mile below the ocean level. (See *Fig. 1.*)

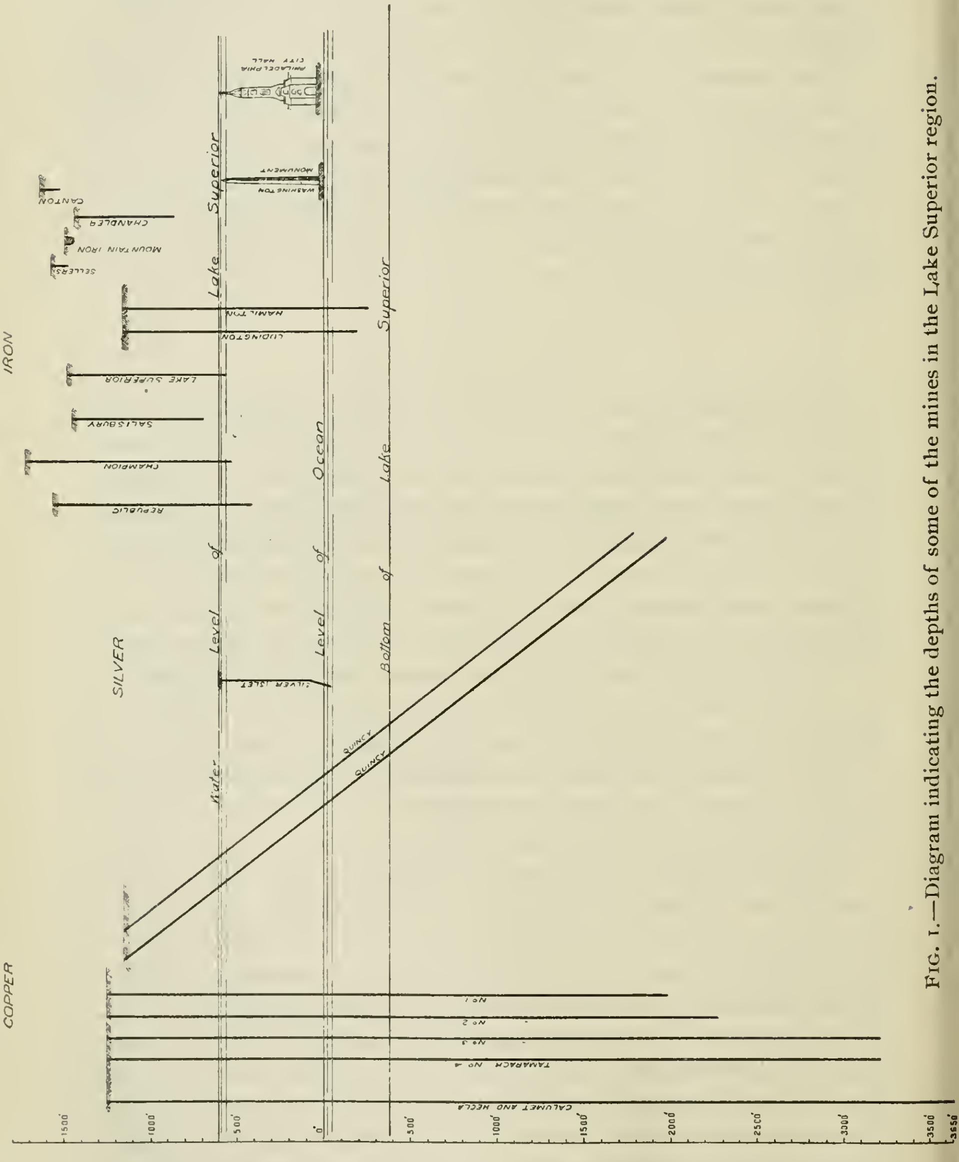


FIG. 1.—Diagram indicating the depths of some of the mines in the Lake Superior region.

It may be instructive to compare the operation of the Lake Superior copper mines with their most active competitor. The mines of the Anaconda Copper Mining Company, in Montana, have produced in fifteen years 400,000 tons of fine copper, with considerable silver and gold, the operations being now 1,200 feet deep. In the same period over 580,000 gross tons of copper were obtained from the Lake Superior mines, but the present output of copper from the Lake Superior region is less than that of Montana.

To illustrate the class of machinery at the Calumet and Hecla copper mines, the dimensions of one pair of quadruple expansion engines, of Philadelphia manufacture, may be given. Each engine has its four cylinders, 18 inches, 27¾ inches, 48 inches and 90 inches in diameter, with a stroke of 60 inches, driving through gearing, conical hoisting drums, 14 feet to 24 feet in diameter, and 12 feet wide, which lift cages carrying 6 tons of ore at the rate of a mile in one and one-half minutes.

At the Tamarack mine an average hoisting speed of 3,200 feet per minute has been obtained by a direct-acting engine built in Milwaukee: having 42 x 84 inch steam cylinders, driving hoisting drums 30 feet in diameter. At the same mine a 32 x 84 inch engine operating a double cone drum 13 feet 6 inches to 36 feet diameter, lifts a cage carrying 2½ to 3 tons 4,500 feet in one and one-half minutes. These are vertical shafts.

At the Quincy mine there are two principal shafts. No. 6, on a slope of 51° 44′, has a total depth of 3,680 feet, the weight of the loads hoisted being about 6 tons. No. 2 shaft, with the same average dip, has a total depth on the slope of 3,954 feet, the loads hoisted weighing about 10 tons each. The governors of the hoisting engines are set so that the maximum speed does not exceed 3,000 feet per minute.

Other important mines in the copper region could add points of interest in the extent of underground workings, machinery equipment, concentrating plant, including pumping machinery of great capacity, refining works, or even in the handling and distribution of the refuse slimes.

As an instance of the economic results achieved in this district the Atlantic mine may be mentioned, which obtains the copper-bearing rock at an average depth of 1,800 feet below the surface. The rock is mined out with explosives, sent to the surface, crushed, hand-sorted, carried to concentrating mill, passed through stamps, to jigs and slime tables, the concentrate is finally conveyed to a smelting works, and the entire operation was carried on with a profit, although the ore yielded but three-fourths of 1 per cent. of copper, and but 10 cents per pound was obtained for the refined metal. In other words, the operation of this mine was successful and profitable when the company received but $1.70 for each ton of "pay-rock" which was mined, crushed, pulverised, concentrated, and the metal refined.

As indicating what has been accomplished in the copper district, the operations of the Quincy Mining Company may be quoted. On a paid-in capital of $200,000, dividends of $7,670,000 had been paid to the close of 1895, the total expenditures having exceeded $20,000,000. During the year 1895, the average force employed was 968 men, of whom 336 were miners, earning an average of $50 each per month. 563,560 tons of rock were mined, from which 16,304,721 pounds of copper were obtained. Still larger figures could be used to indicate the operation of several other mines.

Silver and Gold.—Near Thunder Cape (1,300 feet above the lake), and three-fourths of a mile from the Canadian shore of Lake Superior, is Silver Islet, originally a mass of rock 90 x 90 feet (approximately equal in area to four ordinary city building lots), which projected a few feet above the lake surface, but which has been docked and cribbed until 3 acres are enclosed, to accommodate the shaft house, shops and miners—barracks for operating the mine, from which $3,000,000 in silver have been obtained. Operations were continued to a depth of 640 feet, and extended horizontally 500 feet under Lake Superior. While the enterprise (owing to the expense of mining the limited amount of ore) cannot be considered as having been successful, its bold engineering features are worthy of recognition.

Most of the silver sent from the Lake Superior region occurs in a native state in connection with copper on the Keweenaw Peninsula. Gold mining has been carried to a depth of 850 feet near Ishpeming, Mich., and newer operations to the northwest of Lake Superior have been started.

Iron Ore Mining.—The practical exploitation of Lake Superior iron ores, which have developed an enormous trade, occurred about the same time the copper mines were first operated; but beyond treating the ores in local forges, little use was made of them until the year 1856, when the first iron ore was shipped from Marquette. For a long time the range near Marquette, which bears its name, supplied all of the ore, but in 1877 the Menominee range to the south was exploited, and opened for business. While this range is considered, as in the Lake Superior region, most of its ore is shipped via Lake Michigan, thus saving the delay of locking through the St. Mary's Ship Canal, and having less detention from ice in winter. Seven years later the third and fourth ranges, the Gogebic in Michigan and Wisconsin, and the Vermilion in Minnesota, were opened, and within the past three years another range, the Mesabi in Minnesota, has been attracting attention by the size and character of its deposits, and the ease with which the ore is won. As new ranges were discovered and new mines opened, markets were found for the increased outputs, and nearly 10,500,000 tons were sent from the mines of the Lake Superior district in 1895, enormous quantities having been obtained from individual operations. Up to the close of 1895, eleven mines had each contributed totals of from 3,000,000 to 6,800,000 long tons, as much as 1,000,000 tons were produced by a single operation in one year, and for a decade the average output of one mine has been 500,000 tons per year, while several mines for shorter periods had records almost as large. The total amount of iron ore which has been won from the Lake Superior iron ore mines to date exceeds 100,000,000 gross tons.

Some of the hoisting plants at these mines are excellent examples of mechanical construction, but none are as elaborate as that above described at the Calumet and Hecla copper mine. The Chapin iron ore mine has a vertical compound pumping engine, with cylinders 50 and 100 inches in diameter and 10 feet stroke, designed to deliver 3,000 gallons per minute from a depth of 1,500 feet. The plunger pumps, 28 inches in diameter and 10 feet stroke, are connected to the engine through a horizontal beam, and also to a 40-feet fly-wheel weighing 160 tons.

At this same mine the entire power equipment is arranged to work either with steam or with compressed air, the latter being developed by a waterfall 3 miles distant, and conveyed to the mine in a 30-inch wrought iron pipe laid on the surface and fitted with expansion joints. One of the shafts of the Chapin mine was sunk through quicksand by freezing the sand into solid masses, which were then blasted out.

The methods of mining iron ores vary, according to the character of the deposit, from stripping and mining with the steam shovel, to working with rock drills 1,450 feet below the surface of the earth. Some mines are wrought open cut, but the majority are operated underground, all the different methods of long wall mining, caving, milling, overhand and underhand stoping, as well as the various systems of timbering and filling, being in active use in the iron ore mines of Lake Superior. The character of the ore also varies from soft material, easily handled by the shovel, to rock so hard as to severely test the tools and apparatus employed. Rock drills of the same size and working under similar pressures, which bored 100 to 120 feet in ten hours in the limestone of the Chicago drainage canal, could not cut more than 5 to 6 feet in hard Minnesota, and 18 to 20 feet in hard Marquette ores, in the same time.

A statement of the cost of mining ore at one of the large iron ore mines, from a depth of 500 feet below the surface, shows:

	Cents Per Ton.
Actual mining cost, including labor, explosives, light, etc. . .	44
To which must be added timbering	6
Operating machinery and office expenses	6
Repairs	3¼
Loading and sorting ore	3¼
Insurance and other expenses	2½
A total for ore loaded on cars of	65

for all charges at the mine except royalty and interest

This was an ore of medium hardness, and the quantity of water handled was not excessive.

Iron Ore Shipping Docks.—For the shipment of the iron ore mined in the Lake Superior region, a score of docks fitted with pockets have been erected, at a cost of about $5,000,000. Some of the older docks have been abandoned, and the newer ones embody improvements as to construction, height, handling appliances, etc., and, although the details have been carefully studied out, the cost is sufficiently great to make an appreciable charge for interest and maintenance on each ton of ore handled. The following figures will give an idea of one of the later constructions:

The dock of the Duluth, Mesabi and Northern Railroad, at Duluth, extends into the bay 2,850 feet, its surface being 52·8 feet above the water level, and is equipped with 384 pockets, each with a capacity of 135 tons when trimmed, so that the storage of the dock may be taken in round numbers as 50,000 tons. These pockets are reached by four tracks on the deck of the dock, on which cars with drop bottoms are run. The dock and its approach required 9,250,000 B. M. feet of lumber, and cost $436,000. Twelve boats can be loaded at a time, and 43,000 tons of iron ore have been sent forward from this dock in one day. During the shipping season of 1894 the average cargo delivered per vessel was 2,070 tons, and the average time loading was four hours and seven minutes; but in one instance 2,350 tons of iron ore were placed in a boat in forty-five minutes.

The dock at Marquette, with 270 pockets and very short approach, cost $237,000, and in round numbers a dock proper may be estimated at $1,000 per pocket, or $10 per ton capacity.

The ore shipping docks, although differing in length, width and height, are constructed upon one general plan, viz.: a series of pockets, supported on framing which rests on piles, the pockets each terminating in a door to control the flow of ore into a steel spout weighing 2,500 pounds, which is let down so as to discharge the ore into the hatches of vessels. Over these pockets are the railroad tracks, on which ore is carried by drop-bottom cars.

The length of the twenty iron ore shipping docks, independent of approaches, varies from 559 feet to 2,304 feet, the aggregate of all being about 27,000 feet, or say 5 miles; they contain over 4,200 pockets, and have a capacity of 600,000 long tons, costing approximately $5,350,000. Two more are now building.

Statistics show that the capital invested in the Lake Superior iron ore mines and their equipments amounts to $100,000,000; in iron ore, shipping and receiving docks with approaches, etc., at ports of Lakes Superior and Michigan, $14,000,000; in railroad transportation for iron ore, exclusively to ports on the lakes above-mentioned, $32,000,000; in vessels which are chiefly engaged in the iron ore traffic, $47,000,000; in docks on Lake Erie between Toledo and Buffalo, for receiving and shipping iron ore, $15,000,000; and in railroad transportation of the ore from lower lake ports to furnaces, $28,000,000. The total amount of capital invested in the Lake Superior iron ore trade exclusively is over $250,000,000.

Coal Receiving Docks.—The iron ore shipping docks of Lakes Superior and Michigan are well supplemented by coal receiving docks, where equipments of labor-saving machinery take the coal from the holds of vessels and deliver it onto great stock piles, or directly onto cars.

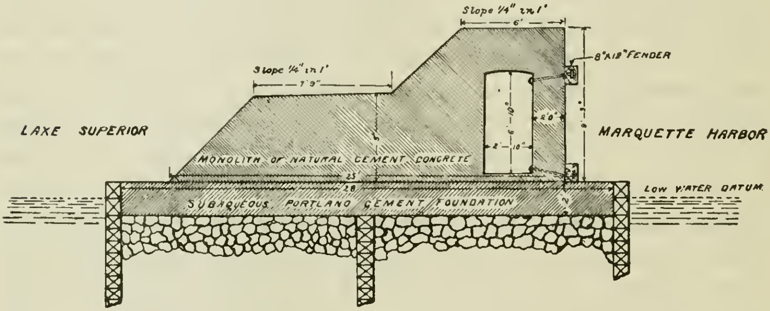
The shipments of coal from Lake Erie ports to Lake Superior have aggregated 3,000,000 net tons in one year, and in the past five years, 13,000,000 net tons have passed westward through the St. Mary's Ship Canal.

While the coal receiving docks are equipped with various devices, most of them may be described as having a hoisting arrangement to lift the loaded buckets from the vessel's hold sufficiently high to drop their contents into cars which run back on trestles and dump automatically, although in some cases the pockets are carried over the stock pile. One impressive plant has immense dome-shaped storage sheds into which the ore is delivered, and from which it is discharged by mechanical conveyors. Another interesting feature is a battery of coke ovens at West Superior, in which coal brought from the lower lakes is coked, a practice which will probably grow with the development of iron production close to the ore mines, where good ores, but not of the quality to stand long shipments, can be cheaply obtained.

Harbor Improvement.—The work of the engineer is evident at Duluth, Superior, Ashland, Marquette and elsewhere, where railroad lines terminate on the upper lakes in enormous grain elevators, flour and lumber mills of great capacity, and representing advanced construction and equipment, while the harbor improvements on the Great Lakes have demanded large outlays of money and the highest engineering skill.

In this connection, the canal entry at Duluth, is interesting as indicative of the progressive spirit of a people determined to attain commercial advancement. Minnesota Point, a long sand spit or peninsula, extends for some 7 miles from near the business center of Duluth to a natural entry opposite Superior, Wisconsin, and is the last of a series of visible bars formed by detrital matter brought down the St. Louis River, meeting the wave action of the lake. The Duluth entry was cut through the peninsula, and is of interest as a problem in harbor improvement, which, up to the present time, has failed to exert the baneful influence which skilled engineers prophesied. A vessel buffetted by severe storms may in a few moments, by means of this short canal, pass from the tempest-tossed waters of Lake Superior into the calm surface of the commodious harbor, known as Superior Bay.

At Marquette, Mich., there is being constructed a breakwater 3,000 feet in length, composed of béton blocks, under the personal direction of Mr. Clarence Coleman, U. S. Assistant Engineer, from plans prepared by Major Sears, U. S A. The blocks (each one weighing 100 tons) form an entire section of the breakwater, 10 feet in length, and are monoliths, moulded in place on a Portland cement subaqueous foundation. The stone used is a hard quartzite, broken to 2-inch and 1½-inch sizes. The mortar was made of Portland cement for all subaqueous work, and with natural cement for the blocks, mixed with coarse, water-washed sand, obtained from the shores of Lake Superior. The concrete base, 2 feet thick, rests upon the crib work of the old breakwater, burlap being spread upon the filling stone in the cribs to receive the Portland cement concrete and prevent undue wash from the bottom. Upon the subaqueous work is constructed the monolithic béton blocks, which are moulded in alternate sections of 10 feet in their longitudinal direction, the intervening spaces of 10 feet between the blocks being subsequently filled in by special forms, making the whole structure continuous. Horizontal planes of weakness are avoided by completing a block without any intermission in depositing concrete when work has once commenced. Vertical planes are created by moulding in sections of 10 feet, so that any settlement which may happen in the crib work will only affect the block under which it may occur; and by cushions of tarred paper, placed between the blocks, it is expected to avoid the consequences of contraction and expansion in the mass of concrete.



CROSS SECTION OF CONCRETE SUPERSTRUCTURE OF BREAKWATER
MARQUETTE MICHIGAN

FIG. 2.

The breakwater has a base of 28 feet in width of Portland concrete, and 23 feet base for the monolithic block, which shows 9 feet 3 inches above the Portland cement base on the harbor side. The gallery, which extends for the entire length of the structure, is intended to be used in giving the keeper access to the harbor light on the outer end of the breakwater during heavy storms. (See *Fig. 2.*)

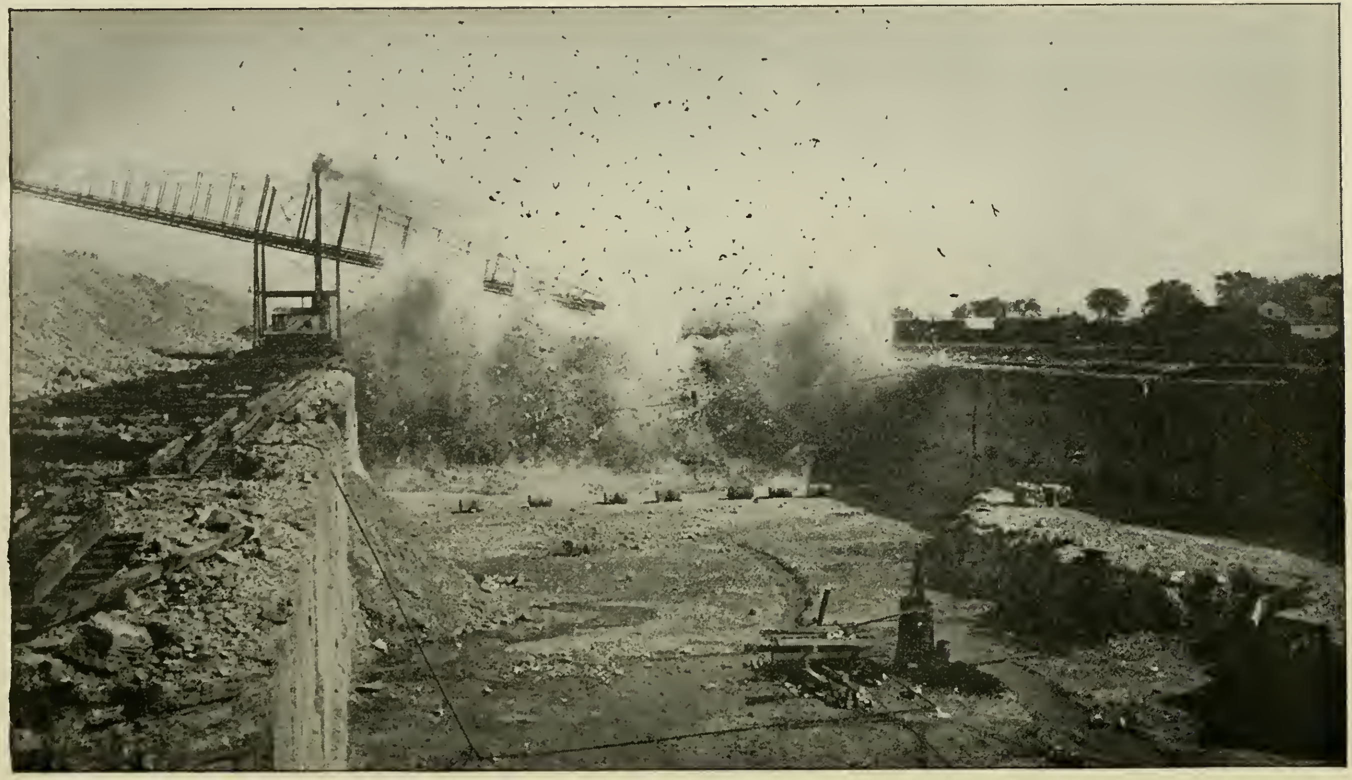


Fig. 3.—Rock Cut, Chicago Drainage Canal. Showing a Cantilever Conveyor, and the Blasting of Rock Across the Face of the Canal.

It will be understood that the structure is intended to be used solely as a breakwater, and is not in any sense a pier for the convenience of vessels.

LAKE MICHIGAN.

Although but few of the points of engineering interest in the Lake Superior region have been indicated, attention may now be devoted to two specialties on Lake Michigan, which also abounds in notable works. Chicago, a great city built up from low ground, alone presents a long array; her water supply and sewage disposition, her harbor, her numerous bridges, her river tunnels, her network of railroads, her great industries, her iron and steel manufacture, now rivalling that of Pittsburgh, Pa., all represent advanced engineering science. It is authoritatively stated that in the season of navigation more tons of freight go from Chicago eastward by water than by rail, a large proportion of the lake fleet prorating with the railways at Erie, Cleveland, Buffalo, etc. In this arrangement the rate by boat per ton mile is about one-fifth to one-sixth that of the connecting railways. "For the longest lake routes 900 miles from Buffalo to Chicago, 1,000 from Buffalo to Duluth, the rate on grain has approximated 60 cents per ton in recent years. The return on coal has been to Chicago 50 cents, and to Duluth as low as 25 cents, or less than is paid to have it shovelled from the gutter across the sidewalk to the coal hole of the city consumer."

Chicago Drainage Canal.—At present, public attention is directed to the great work of the Chicago Drainage Canal, primarily designed to discharge the sewage of the city of Chicago through the Illinois and Mississippi Rivers and furnish a large amount of water-power, but which its projectors hope will ultimately connect the lakes with the Gulf of Mexico for the purposes of navigation.

This canal, with depths of from 22 to 26 feet, has a greater area of gross section than either the Suez, Manchester or North Sea Canals.

The work is carried on under the laws of the State of Illinois, which provide for a commission to take lands, raise money and make contracts, the cost of construction being borne by the city of Chicago, under what is known as the Drainage District, and the moneys raised by taxation. The canal is now being built between Chicago and Lockport, a distance of about 34 miles; 12 or 14 miles of this work is through rock; 10 miles through clay, and 10 miles through a mixture of clay, indurated earth and rock, the rock lying in the bottom.

The rock sections are 160 feet wide and about 32 feet deep, In sections where the earth overlies the rock a retaining wall is built from the rock up to the top of the bank. The entire earth sections are sloped; the width in the bottom of the earth sections running from 108 to 160 feet, and the top from 200 to 320 feet; the sides are to be rip-rapped. The top lifts of the dirt sections have been taken off generally with wagons and wheel scrapers, while the bottom lifts have been taken out with steam shovels and tram cars. The average price of the rock excavated per yard has been about 76 cents, dirt sections from 22 to 28 cents per yard. The Desplaines River also had to be diverted and straightened for about 14 miles, and was excavated 200 feet wide and about 4 feet deep.

On the rock sections the top lifts were taken out with inclines and carts, the two lower benches being removed either with cantilevers, cableways or with swing derricks. The most successful work has been credited to the cantilevers and the cableways, but the swing derricks have done good service.

Mr. James F. Lewis, of Chicago, reports that the cableways cost about $12,000, the cantilevers $28,000 each. But one contracting firm owned cantilevers, other firms employed cantilevers, etc., the rock being taken out under contract by the Hoisting Company. The original contractors put the material into the buckets, the sub-contractors supplied the equipment and power for hoisting and dumping it.

The first operation on the canal, after taking off the top soil on the rock sections, was channelling down the sides with channelling machines, the cut being made in three benches. After this from fourteen to sixteen holes were drilled in a row across the 160 feet section, from 10 to 12 feet back of the face. These holes were fired simultaneously by electricity. It is reported that the blasting was accomplished with an average consumption of one-half pound of 40 per cent. dynamite to the cubic yard. This cost the parties 10 cents per pound, delivered on the work. (See *Fig. 3.*)

This work has demonstrated that about 4 to 5 yards of rock per man could be handled in carts, about 6 to 8 in cars, and from 8 to 10 with cantilevers and cableway buckets per day.

The greater part of the drilling, pumping and some hoisting, has been done with compressed air, one air plant covering one mile of work, but several sections have been operated entirely with steam from a number of boilers; however, the general verdict is strongly in favor of compressed air. Mr. Lewis states the rock drills have bored all the way from 90 to 130 feet per day, or 13 feet per hour.

The fall of 1896 should see the canal to the city line completed for the 34 miles, but it will not achieve its purpose until Chicago builds lateral canals to cut off the sewage which now runs into the lake. These lateral canals will turn all the sewage into the Chicago River and from that into the canal.

The amount of rock excavation exceeds 12,000,000 cubic yards, and the total quantity of rock and earth to be moved is about 40,000,000 cubic yards; when completed the work will have cost $27,000,000.

Thus Chicago is expending $27,000,000 for its drainage, with a possibility of improved transportation facilities, while the State of Pennsylvania hesitated to appropriate 2 per cent. of that amount to facilitate the removal of obstructions in the Delaware River, which are driving trade away from this stream.

The following data concerning the labor employed and wages paid is excerpted from a report by Joseph Gruenhut, labor statistician:

"For summer months the following working force was employed (more or less) on the canal by the contractors on all sections: 45 superintendents, 32 bookkeepers and clerks, 280 foremen and time-keepers, 3 civil engineers, 73 steam shovel engineers, 73 crane men, 12 first levermen, 8 second levermen, 12 first hookers, 12 second hookers, 9 riggers, 7 cableway repairers, 240 engineers and pumpmen, 275 firemen, 50 trainmen, 210 drillers, 113 channellers, 11 electricians, 37 machinists, 100 stone masons, 101 carpenters and 17 helpers, 69 blacksmiths and 46 helpers, 12 boiler-makers and 7 helpers, 1 oil man, 1 tool man, 50 watermen and boys, 450 teamsters, 6,000 laborers—a total of 8,356.

"The number of persons employed in the commissary and in the camp boarding houses may be estimated at 344, which would make a grand total of 8,700 persons directly paid in the camps of the Drainage Canal.

"The average wages on the Drainage Canal are as follows:

"*Daily Wages*—Laborers, \$1.50–\$1.75; teamsters, \$1.50–\$1.60; drillers, \$1.75–\$2.00; trainmen, \$1.75–\$2.00; firemen, \$1.75; channellers, \$2.50–\$3; first levermen, \$2.20; second levermen, \$1.50; first hookers, \$1.75; second hookers, \$1.50; riggers, \$2.25; cableway repairers, \$2.25; machinists, \$2–\$2.50; carpenters, \$2–\$2.25; blacksmiths, \$2.50–\$3; boiler-makers, \$3.50; stonemasons, \$3.50–\$4.

"*Monthly Wages*—Superintendents, \$100–\$150; time-keepers, \$50–\$100; bookkeepers and clerks, \$60–\$125; foremen, \$60,–\$80; engineers and pumpmen, \$50–\$80; electricians, \$75–\$90; civil engineers, \$90–\$100; steam shovel engineers, \$125; cranemen, \$90–\$100."

Screw Pumping Engine.—The city of Milwaukee has an interesting installation in a screw pumping engine, which, by discharging a large volume of water from Lake Michigan into the Milwaukee River, flushes away sewage which had become a nuisance. A four-bladed propeller, 14 feet in diameter, keyed to the crank shaft of a vertical compound engine, with steam cylinders 19 and 38 inches in diameter and 4 feet stroke, causes, at fifty-two revolutions per minute, a volume of 40,000 cubic feet per minute to pass through a tunnel ½ mile long into the river, which, at the discharge, is 3 feet above the ordinary lake level. When tested, a duty of 76,000,000 foot-pounds per 100 pounds of coal fired, or

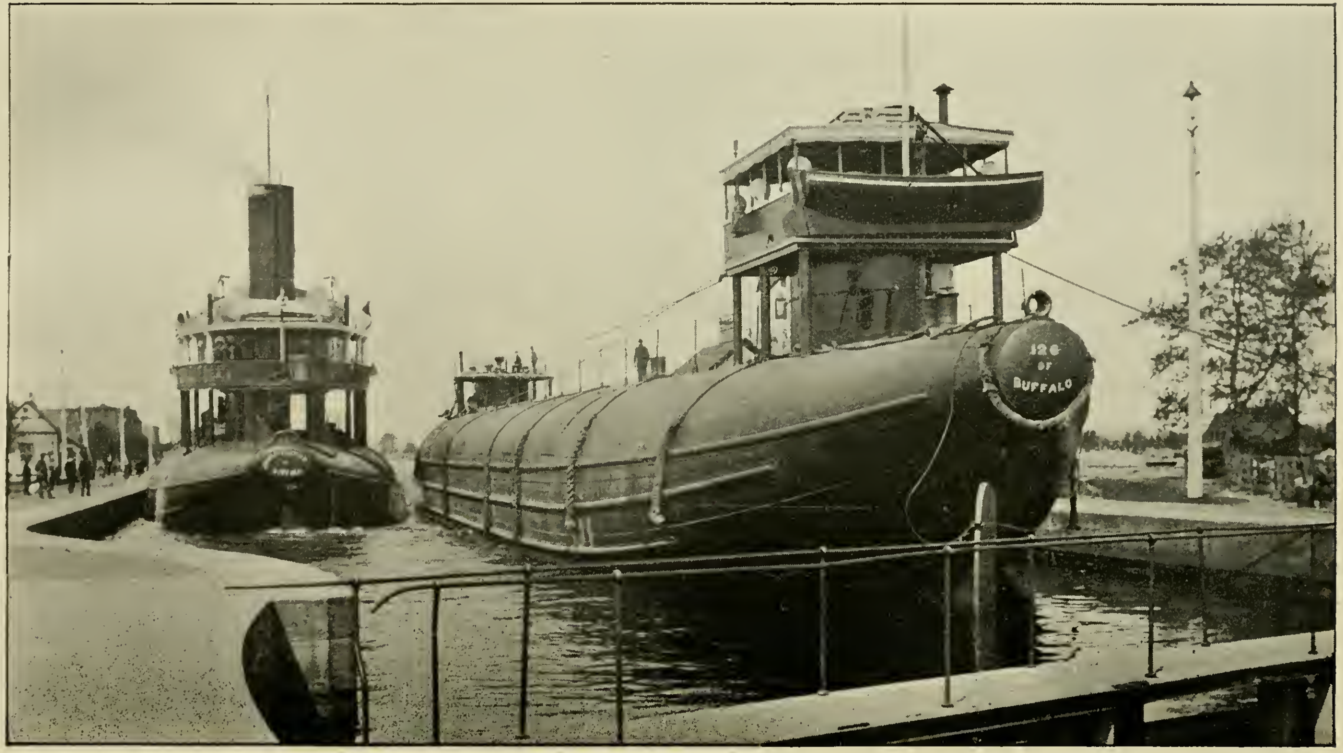


FIG. 4.—"WHALE-BACK" PROPELLER AND BARGE IN THE AMERICAN LOCK, SAULT STE. MARIE, MICH.

102,000,000 foot-pounds per 100 pounds of steam used, was reported.

Milwaukee, like Chicago, has powerful and economical engines for water supply and for sewage disposal, a tunnel into the lake for water, breakwaters, swing bridges, imposing buildings, large industrial and railroad structures, etc.

ST. MARY'S SHIP CANAL.

A statement of the commerce through the St. Mary's Falls Canal since its opening in 1855 would be practically a *résumé* of the progress of what may be called the Lake Superior district, and an indication of the rapid development of the northern portion of the United States, and yet this would not include the great traffic which did not reach Lake Superior, for vessels from Lake Michigan and the lower lakes do not have to pass this canal.

To illustrate how progress has exceeded expectations, it is interesting to refer to a letter written by the late E. B. Ward, of Detroit (one of the most progressive men of his time), who in 1853 expressed a conviction that a lock 350 feet long and 70 feet wide would be larger than would ever be needed for the Lake Superior traffic, and stated that he considered a lock 260 feet long by 60 feet wide ample for the present century.

The two locks constructed in 1855, however, were made 350 feet by 70 feet, with a lift of 9 feet each, and passed vessels drawing 12 feet of water. In the first ten years of their existence the registered tonnage annually passing increased from 100,000 to 570,000, being augmented in the second decade to over 1,000,000 tons. The demands of lake traffic soon required a new lock, which was completed in 1881, its length being 515 feet, width 80 feet (narrowed at the portals to 60 feet), the lift was 18 feet, with a depth of 16 feet on the mitre sill. For years this lock has been totally inadequate, and during the season of navigation there has been a continued congestion of vessels both above and below, it having passed, during seven and one-half months in the year 1895, 16,793 vessels, with a total registered tonnage of over 16 000,000. (See *Fig. 4.*)

The report of the Manchester Ship Canal shows that in 1895 the tonnage passing through it was but one-tenth of that passing the St. Mary's Ship Canal. Since 1891 the traffic through the Suez Canal, in twelve months, has been below that of the St. Mary's Canal for less than eight months, the number of vessels for three years being:

	1893.	*1894.*	*1895.*
Suez Canal, 12 months	3,341	3,352	3,434
St. Mary's Ship Canal, 8 months .	12,008	14,491	17,956

A new lock, 800 feet long and 100 feet wide throughout, with a lift of 18 feet and a depth of 21½ feet on the mitre sill, is nearly completed, at a cost of $5,000,000, and will be opened by the United States Government to commerce in 1896, while on the opposite side of the St. Mary's River the Canadian Government have within the last few months opened for traffic a lock 900 feet long and 60 feet wide.

To those familiar with the locks used on our ordinary river canals, a recital of dimensions scarcely makes them appreciated. To assist such appreciation we may consider that to fill this new 800 x 100 feet lock will require 11,000,000 gallons of water, that each of the wings of the lower gate, which are made of steel, weigh 175 tons, and that four fairly large vessels, say 350 to 375 feet long, can be carried through at a single lockage.

The value of the over 13,000,000 tons of freight passing the present lock during the seven and one-half months that navigation was open in the year 1894, exceeded $143,000,000, and as the average distance the freight was carried by water was 821 miles, the traffic represented a total ton-mileage of 11,000,000,000, the cost of carrying per ton-mile being slightly less than one mill. Corresponding figures for the traffic of 1895 are now in the course of preparation.

The freight which passed through the St. Mary's Canal in 1894 as represented by the values may be generally subdivided thus: 40 per cent. flour and wheat, 14 per cent. copper, 12 per cent. iron ore, 8 per cent. lumber and 6 per cent. coal, the balance being unclassified and diversified freight.

An idea of the quantities moved, however, may be had from the 2,750,000 tons of coal, 6,500,000 tons* of iron ore, 9,000,000 barrels of flour, 36,000,000 bushels† of grain, 250,000 barrels of salt, 60,000 tons of iron, 100,000 tons of copper, 723,000,000 feet B. M. lumber, etc.

[*To be concluded.*]

CHEMICAL SECTION.

Stated Meeting, held April 21, 1896.

DR. HARRY F. KELLER, President, in the Chair.

SEPARATION OF SILVER FROM GOLD BY VOLATILISATION.

BY DR. JOSEPH W. RICHARDS, of the Lehigh University.

In making the quantitative blowpipe assay for gold and silver, it is usual to treat 100 milligrams of ore at a single fusion, yielding buttons which are too small to be weighed accurately, but whose weight must be found by measuring carefully their horizontal diameters.

As determined by Plattner (and often verified in the writer's experience), silver buttons weigh 0·6346 of the weight of spheres of silver of the same diameter as measured, and gold buttons 0·7506 of the weight of gold spheres. The buttons obtained usually weigh 0·5 to 1·5 milligrams, and the separation of the silver from the gold in buttons so small is a matter of considerable difficulty. Plattner remarks that no satisfactory method of separation in the dry way is known, and recommends the parting by nitric acid. Working, however, with buttons smaller than pin-heads, it is extremely difficult to boil two or three times with nitric acid, to wash until the silver salt is all removed, and then to gather and melt down the gold, without losing a considerable proportion of the gold in three or four directions.

---

* 8,000,000 tons in 1895.

† 46,000,000 bushels in 1895.

Knowing that, on long heating, silver gives a coating of oxide on charcoal, and that gold does not, I made experiments to determine whether silver could be thus separated from gold, and have found the method practicable. On heating to a bright-yellow heat (not to whiteness) upon charcoal an alloy of gold and silver, before a sharp-pointed oxidising flame, the silver volatilises easily and steadily until there is less than 5 per cent. of silver remaining in the gold. I estimate this volatilisation to take place a little above the melting point of copper, say at 1,100–1,200° C. To remove the remainder of the silver, the heat is raised nearly to whiteness, or to about the melting point of steel (1,500° C). When the silver is entirely eliminated, the gold, at this temperature, begins to volatilise also; in fact, a trace of gold will be carried off with the last of the silver, and if the ash of the charcoal be white it will show a faint crimson coating close to the assay. When this coating is heavy enough to be seen without the use of a lens, the silver has been completely volatilised and the remaining button is pure gold. The amount of gold necessary to give this coating is too small to be determined by weighing or measuring.

Having explained the principle made use of, I will give the further details of conducting the operation. The charcoal should be dense, so as not to burn away too quickly. Too light a charcoal will not stand the five or ten minutes' application of the oxidising flame without burning through the piece. It should also leave a white ash under the oxidising flame, so as to furnish a background on which to see the crimson gold coating which determines the end of the operation. I have found the dense, hard charcoal made by Johnson & Co., of New York, to answer these requirements admirably. It is well, also, to work with a porcelain saucer, or large sheet of clean paper, under the flame, to catch the button in case it should be blown from the charcoal.

In order to perform this separation without excessive exertion, I would recommend that a gas flame not over 2 centimeters high be used, that the tip of the blowpipe be advanced at least halfway through the flame, and inclined somewhat sharply downwards, at an angle of about 45°. By observing these simple directions, a very sharp-pointed, needle-like oxidising flame will be produced, about 1 centimeter in length to the blue tip, which I have found the best for the purpose in view. To produce this the blowing need not be strong, but it should be kept up steadily. The button, in a shallow cavity near the end of the stick of charcoal, is now brought directly in front of the point of the flame, at about 1 to 2 millimeters from the visible blue tip. Its position, of course, is regulated by the temperature observed. The button ton should not, at this stage, be heated to whiteness, else the silver will boil and cause a loss by sputtering. The charcoal is held inclined towards the flame at an angle of about 30°, so that the flame descends almost vertically upon the button, and thus decreases the liability of its displacement by the force of the blast.

It will be found practicable to continue a blowing for about three minutes without discomfort, at the end of which time the operator may stop to observe the color of the button. Supposing the alloy, on starting, to have been white, it will usually become pale yellow in from three to six minutes. When the alloy exhibits a brass-yellow color, the heat should be raised, and the next blowing continued for not over two minutes. At the end of this time the alloy will usually exhibit nearly the pure gold color, but no gold coating, or, at most, only a trace of it will be seen on the charcoal. After this, the heat should be raised to nearly whiteness, and then continued for not over one minute at a time. If a faint gold coating appears, further heating for one minute will usually develop a distinct crimson coating, visible without the lens, and the alloy will show the pure gold color. It is then taken out, cupelled and measured.

If the amount of gold present be very small, it is difficult to continue volatilising silver after the button gets smaller than $\frac{1}{4}$ millimeter in diameter. The difficulty is caused by the ash of the charcoal, which, fusing to a slag, envelopes the button. To continue the removal of the silver, should the button arrive at this size without showing the gold color, the operator cupels and measures a pure gold button of about the same size and adds it to the button being treated. The enlarged button is now worked down to pure gold, as before, removed, cupelled and measured. The weight of gold obtained is diminished by the amount added, the difference giving that in the ore.

If the heating to incipient whiteness be continued two or three minutes after the visible gold coating is obtained, a very pretty gold coating of bright, peach-blossom color is obtained, and a sensible amount of gold is lost by volatilisation. A pure gold button, 1 millimeter in diameter, weighing 7·58 milligrams, lost 0·03 milligrams (0·4 per cent.) each minute that it was heated to whiteness, and in five minutes gave a beautiful crimson coating. A silver button of similar size lost 18 per cent. of its weight, each minute, at only a bright-yellow heat. I estimate the point at which gold begins to volatilise as about the melting-point of soft steel (1,500° C.). It is certainly considerably below the melting-point of platinum (1,775° C.).

In conclusion, I wish to say that I have tested this method of separation in many different ways, with large and small buttons, and upon alloys rich and poor in gold, and have found the separation to be absolute when the conditions above described are properly observed. I have repeatedly alloyed a gold button with different amounts of silver, and then driven off the silver, the button, after two or three of such separations, remaining of exactly the same size and weight as at the start. In proposing this method of separation, I do not wish to disguise the fact that, to ensure success, it demands a steady hand and an experienced operator, and some practice; but I believe that any one who has mastered the art of blowpiping sufficiently to make gold and silver assays, can, in a short time, master this method of separating the gold and silver.

[In the discussion of the above paper, it was suggested that the method might be practicable in the ordinary assay of gold and silver, as, at assay offices, if an electrically heated furnace could be devised, in which the buttons could be placed on suitable supports, and kept at the proper temperature to volatilise silver, with a current of air passing over them. The movement to the hottest part of the furnace would suffice to remove the last traces of silver, just as the last traces of lead are removed in cupellation in an ordinary muffle. The process of removing the silver would then resemble cupellation in its general outlines, except that the temperature would be about 300° to 500° higher.]

ELECTRICAL SECTION.

Stated Meeting, December 19, 1895.

MR. CARL HERING, President, in the Chair.

MECHANICAL CONCEPTIONS OF ELECTRICAL PHENOMENA.

BY PROF. A. E. DOLBEAR,
Tuft's College, Massachusetts.

> And now we might add something concerning a most subtile spirit which pervades and lies hid in all gross bodies, by the force and action of which spirit the particles of bodies attract each other at near distances, and cohere if contiguous, and electric bodies operate at greater distances as well repelling as attracting neighboring corpuscles, and light is emitted, reflected, inflected and heats bodies, and all sensation is excited and members of animal bodies move at the command of the will.—*Newton, in Principia.*

In Newton's day the whole field of nature was practically lying fallow. No fundamental principles were known until the law of gravitation was discovered. This law was behind all the work of Copernicus, Kepler and Galileo, and what they had done needed interpretation. It was quite natural that the most obvious and mechanical phenomena should first be reduced, and so the *Principia* was concerned with mechanical principles applied to astronomical problems. To us, who have grown up familiar with the principles and conceptions underlying them, all varieties of mechanical phenomena seem so obvious, that it is difficult for us to understand how any one could be obtuse to them; but the records of Newton's time, and immediately after this, show that they were not so easy of apprehension. It may be remembered that they were not adopted in France till long after Newton's day. In spite of what is thought to be reasonable, it really requires something more than complete demonstration to convince most of us of the truth of an idea, should the truth happen to be of a kind not familiar, or should it chance to be opposed to our more or less well-defined notions of what it is or ought to be. If those who labor for and attain what they think to be the truth of any matter, were a little better informed about mental processes and the conditions under which ideas grow and displace others, they would be more patient with mankind, and teachers of every rank might discover that what is often called stupidity may be no more than mental inertia, which can no more be made active by willing than can the movement of a cannon ball by a like effort. We grow into our beliefs and opinions upon all matters, and scientific ideas are no exceptions.

Whewell, in his "History of the Inductive Sciences," says that the Greeks made no headway in physical science because they lacked appropriate ideas. The evidence is overwhelming that they were as observing, as acute, as reasonable as any who live to-day. With this view, it would appear that the great discoverers must have been men who started out with appropriate ideas: were looking for what they found. If, then, one reflects upon the exceeding great difficulty there is in discovering one new truth and the immense amount of work needed to disentangle it, it would appear as if even the most successful have but indistinct ideas of what is really appropriate, and that their mechanical conceptions become clarified by doing their work. This is not always the fact. In the statement of Newton, quoted, he speaks of a spirit which lies hid in all gross bodies, etc., by means of which all kinds of phenomena are to be explained; but he deliberately abandons that idea when he comes to the study of light, for he assumes the existence and activity of light corpuscles, for which he has no experimental evidence; and the probability is that he did this because the latter conception was one which he could handle mathematically, while he saw no way for thus dealing with the other. His mechanical instincts were more to be trusted than his carefully calculated results; for, as all know, what he called "spirits," is what to-day we call the ether, and the corpuscular theory of light has now no more than a historic interest. The corpuscular theory was a mechanical conception, but each such corpuscle was ideally endowed with qualities which were out of all relations with the ordinary matter with which it was allied.

Until the middle of the present century the reigning physical philosophy held to the existence of what were called imponderables. The phenomena of heat were explained as due to an imponderable substance called "caloric," which ordinary matter could absorb and emit. A hot body was one which had absorbed an imponderable substance. It was, therefore, no heavier than before, but it possessed ability to do work proportional to the amount absorbed. Carnot's ideal engine was described by him in terms that imply the materiality of heat. Light was another imponderable substance maintained by Sir David Brewster as long as he lived. Electricity and magnetism were imponderable fluids, which, when allied with ordinary matter, endowed the latter with their peculiar qualities. The conceptions in each case were properly mechanical ones *part* (but not all) *of the time;* for when the immaterial substances were dissociated from matter, where they had manifested themselves, no one concerned himself to inquire as to their whereabouts. They were simply off duty, but could be summoned, like the genii in the story of Aladdin's Lamp. Now, a mechanical conception of any phenomenon, or a mechanical explanation of any kind of action, must be mechanical all the time, the antecedents as well as the consequents. Nothing else will do except a miracle.

During the fifty years, from about 1820 to 1870, a somewhat different kind of explanation of physical events grew up. The interest that was aroused by the discoveries in all the fields of physical science—in heat, electricity, magnetism and chemistry—by Faraday, Joule, Helmholtz and others, compelled a change of conceptions; for it was noticed that each special kind of phenomenon was preceded by some other definite and known kind; as, for instance, that chemical action preceded electrical currents, that mechanical or electrical activity resulted from changing magnetism, and so on. As each kind of action was believed to be due to a special force, there were invented such terms as mechanical force, electrical force, magnetic, chemical and vital forces, and these were discovered to be convertible into one another, and the "doctrine of the correlation of the physical forces" became a common expression in philosophies of all sorts. By "convertible into one another" was meant that, whenever any given force appeared, it was at the expense of some other force; thus, in a battery, chemical force was changed into electrical force; in a magnet, electrical force was changed into magnetic force, and so on. The idea here was the *transformation of forces*, and *forces* were not so clearly defined that one could have a mechanical idea of just what had happened. That part of the philosophy was no clearer than that of the imponderables which had largely dropped out of mind. The terminology represented an advance in knowledge, but was lacking in lucidity, for no one knew what a force of any kind was.

The first to discover this and to repudiate it were the physiologists, who early announced their disbelief in a vital force, and their belief that all physiological activities were of purely physical and chemical origin, and that there was no need to assume any such thing as a vital force. Then came the discovery that chemical force, or affinity, had only an adventitious existence, and that, at absolute zero, there was no such activity. The discovery of, or rather the appreciation of, what is implied by the term *absolute zero*, and especially of the nature of heat itself, as expressed in the statement that heat is a mode of motion, dismissed another of the so-called forces as being a metaphysical agency having no real existence, though standing for phenomena needing further attention and explanation—and by explanation is meant *the presentation of the mechanical antecedents for a phenomenon, in so complete a way that no supplementary or unknown factors are necessary.* The train moves because the engine pulls it; the engine pulls because the steam pushes it.

There is no more necessity for assuming a steam force between the steam and the engine, than for assuming an engine force between the engine and the train. All the processes are mechanical, and have to do only with ordinary matter and its conditions, from the coal pile to the moving freight, though there are many transformations of the forms of motion and of energy between the two extremes.

During the past thirty years, there has come into common use another term, unknown in any technical sense before that time, namely, *energy*. What was once called the conservation of force is now called the conservation of energy, and we now often hear of forms of energy. Thus, heat is said to be a form of energy, and the forms of energy are convertible into one another, as the so-called forces were formerly supposed to be transformable into one another. We are asked to consider gravitative energy, heat energy, mechanical energy, chemical energy, electrical energy. When we inquire what is meant by energy, we are informed that it means ability to do work, and that work is measurable as a pressure into a distance, and is specified as foot-pounds. A mass of matter moves because energy has been spent upon it and has acquired energy equal to the work done on it, and this is believed to hold true, no matter what the kind of energy was that moved it. If a body moves, it moves because another body has exerted pressure upon it, and its energy is called *kinetic energy;* but a body may be subject to pressure and not move appreciably, and then the body is said to possess potential energy. Thus, a bent spring and a raised weight are said to possess potential energy. In either case, *an energised body receives its energy by pressure, and has ability to produce pressure on another body.* Whether or not it does work on another body depends on the rigidity of the body it acts upon. In any case, it is simply a mechanical action—body A pushes upon body B (*Fig. 1*). There is no need to assume anything more mysterious than mechanical action. Whether body B moves in this way or that depends upon the direction of the push, the point of its application. Whether the body be a mass as large as the earth or as small as a molecule, makes no difference in that particular. Suppose, then, that *a* (*Fig. 2.*) spends its energy on *b*, *b* on *c*, *c* on *d*, and so on. The energy of *a* gives translatory motion to *b*, *b* sets *c* vibrating, and *c* makes *d* spin on some axis. Each of these has had energy spent on it, and each has some form of energy different from the other, but no new factor has been introduced between *a* and *d*, and the only factor that has gone from *a* to *d* has been motion—motion that has had its direction and quality changed, but not its nature. If we agree that energy is neither created nor annihilated by any physical process, and if we assume that *a* gave to *b* all its energy, that is, all its motion; that *b* likewise gave its all to *c*, and so on; then the succession of phenomena from *a* to *d* has been simply the transference of a definite amount of motion, and, therefore, of energy, from the one to the other; for *motion has been the only variable factor.* If, furthermore, we should agree to call the translatory motion α, the vibratory motion β, the rotary γ, then we should have had a conversion of α into β, of β into γ. If we should consider the amount of the transference instead of the kind of motion, we should have to say that the α energy had been transformed into β and the β into γ.

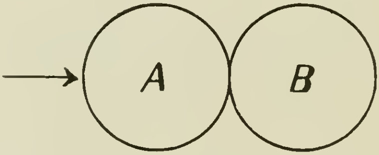


FIG. 1.

What a given amount of energy will do depends only upon its *form;* that is, the kind of motion that embodies it.

The energy spent upon a stone thrown into the air, giving it translatory motion, would, if spent upon a tuning fork, make it sound, but not move from its place; while if spent upon a top, would enable the latter to stand upon its point as easily as a person stands on his two feet, and to do other surprising things, which otherwise it could not do. One can, without difficulty, form a mechanical conception of the whole series without assuming imponderables, or fluids or forces. Mechanical motion only, by pressure, has been transferred in certain directions at certain rates. Suppose now that some one should suddenly come upon a spinning top (*Fig. 3*) while it was standing upon its point, and, as its motion might not be visible, should cautiously touch it. It would bound away with surprising promptness, and, if he were not instructed in the mechanical principles involved, he might fairly well draw the conclusion that it was actuated by other than simple mechanical principles, and, for that reason, it would be difficult to persuade him that there was nothing essentially different in the body that appeared and acted thus, than in a stone thrown into the air; nevertheless, that statement would be the simple truth.

All of our experience, without a single exception, enforces the proposition that no body moves in any direction, or in any way, except when some other body *in contact* with it presses upon it. The action is direct. In Newton's letter to his friend Bentley, he says: "That one body should act upon another through empty space, without the meditation of anything else by and through which their action and pressure may be conveyed from one to another is to me so great an absurdity that I believe no man who has in philosophical matters a competent faculty of thinking can ever fall into it."

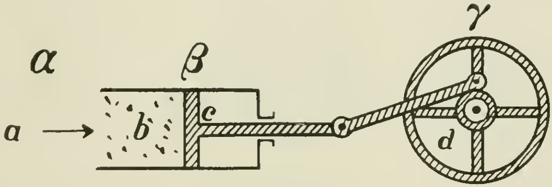


FIG. 2.

For mathematical purposes, it has sometimes been convenient to treat a problem as if one body could act upon another without any physical medium between them; but such conception has no degree of rationality, and I know of no one who believes in that as a fact. If this be granted, then our philosophy agrees with our experience, and every body moves because it is pushed, and the mechanical antecedent of every kind of phenomenon is to be looked for in some adjacent body possessing energy—that is, the ability to push or produce pressure.

It must not be forgotten that energy is not a simple factor, but is always a product of two factors: a mass with a velocity, a mass with a temperature, a quantity of electricity into a pressure, and so on. One may sometimes meet the statement that matter and energy are the two realities; both are spoken of as entities. It is much more philosophical to speak of matter and motion, for in the absence of motion there is no energy, and the energy varies with the amount of motion; and furthermore, to understand any manifestation of energy one must inquire what kind of motion is involved. This we do when we speak of mechanical energy as the energy involved in a body having a translatory motion; also, when we speak of heat as a vibratory, and of light as a wave motion. To speak of energy, without stating or implying these distinctions, is to speak loosely and to keep far within the bounds of actual knowledge. To speak thus of a body possessing energy, or expending energy, is to imply that the body possesses some kind of motion and produces pressure upon another body because it has motion. Tait and others have pointed out the fact that what is call potential energy must, in its nature, be kinetic. He says: "Now it is impossible to conceive of a truly dormant form of energy, whose magnitude should depend, in any way, upon the unit of time; and we are forced to conclude that potential energy, like kinetic energy, depends (even if unexplained or unimagined) upon motion." All this means that it is now too late to stop with energy

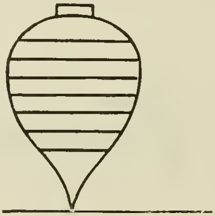


FIG. 3.

as a final factor in any phenomenon, that the *form of motion* which embodies the energy is the factor that determines *what* happens, as distinguished from how *much* happens. Here, then, are to be found the distinctions which have heretofore been called forces; here is embodied the proof that direct pressure of one body upon another is what causes the latter to move, and that the direction of movement depends on the point of application, with reference to the center of mass.

It is needful now to look at the other term in the product we call energy, namely, the substance moving, sometimes called matter or mass. It has been mentioned that the idea of a medium filling space was present with Newton, but his gravitation problem did not require that he should consider other factors than masses and distances. The law of gravitation as considered by him was: Every particle of matter attracts every other particle of matter with a stress which is proportional to the product of their masses, and inversely to the squares of the distance between them. Here we are concerned only with the statement that every particle of matter attracts every other particle of matter. Everything then that possesses gravitative attraction is matter in the sense in which that term is used in this law. If there be any other substance in the universe that is not thus subject to gravitation, then it is improper to call it matter, otherwise the law should read: "Some particles of matter attract," etc.; which will never do.

We are now assured that there is something else in the universe which has no gravitative property at all, namely, the ether. It was first imagined in order to account for the phenomena of light, which was observed to take about eight minutes to come from the sun to the earth. Then Young applied the wave theory to the explanation of polarisation and other phenomena; and, in 1851, Foucault proved experimentally that the velocity of light was less in water than in air, as it should be if the wave theory be true, and this has been considered a crucial experiment which took away the last hope for the corpuscular theory and demonstrated the existence of the ether as a space-filling medium capable of transmitting light waves known to have a velocity of 186,300 miles per second. It was called the luminiferous ether, to distinguish it from other ethers which had also been imagined, such as electric ether for electric phenomena, magnetic ether for magnetic phenomena, and so on—as many ethers as there were different kinds of phenomena to be explained.

It was Faraday who put a stop to the invention of ethers, by suggesting that the so-called luminiferous ether might be the one concerned in all the different phenomena, and who pointed out that the arrangement of iron filings about a magnet was indicative of the direction of the stresses in the ether. This suggestion did not meet the approval of the mathematical physicists of his day, for it necessitated the abandonment of the conceptions they had worked with, as well as the terminology which had been employed, and made it needful to reconstruct all their work to make it intelligible—a labor which was the more distasteful as it was forced upon them by one who, although expert enough in experimentation, was not a mathematician, and who boasted that the most complicated mathematical work he ever did was to turn the crank of a calculating machine; who did all his work, formed his conclusions, and then said: "The work is done; hand it over to the computers."

It has turned out that Faraday's mechanical conceptions were right. Everyone now knows of Maxwell's work, which was to start with Faraday's conceptions as to magnetic phenomena and follow them out to their logical conclusions, applying them to molecules and their reactions upon the ether. Thus he was led to conclude that light was an electro-magnetic phenomenon; that is, that the waves which constitute light and waves produced by changing magnetism were identical in their nature, were in the same medium, traveled with same velocity, were capable of refraction, and so on. Now, that all this is a matter of common knowledge to-day, it is curious to look back no further than ten years. Maxwell's conclusions were adopted by scarcely a physicist in the world. Although it was known that inductive action traveled with finite velocity in space, and that an electromagnet would affect the space about it practically inversely as the square of the distance, and that such phenomena as are involved in telephonic induction between circuits could have no other meaning than the one assigned by Maxwell, yet nearly all the physicists failed to form the only conception of it that was possible, and waited for Hertz to devise apparatus for producing interference before they grasped it. It was even then so new, to some, that it was proclaimed to be a demonstration of the existence of the ether itself, as well as a method of producing waves short enough to enable one to notice interference phenomena. It is obvious that Hertz himself must have had the mechanics of wave motion plainly in mind, or he would not have planned such experiments. The outcome of it all is, that we now have experimental proof, as well as theoretical reason, for believing that the ether, once called luminiferous, is concerned in all electric and magnetic phenomena, and that waves set up in it by electro-magnetic actions are capable of being reflected, refracted, polarised, and twisted, the same as ordinary light waves can be, and that the same laws are applicable to both.

But this ether has been studied in other ways. The light of stars reaches us from space depths so profound that it requires thousands of years, traveling at the high rate of 186,000 miles a second, to reach the earth, and every increase of aperture of our telescopes shows the existence of others still more remote.

For us, the ether is practically *illimitable*; it has no boundaries. If it had boundaries, light waves would be reflected from it in every direction, and the whole canopy of the sky would be luminous all the time. Investigation as to the minuteness of some waves and the conditions for producing such waves has led to the conclusion that the ether is not granular; that is, it is *non-atomic*. It is described as being a *continuous* medium, to signify that there are no pores or interstices in it, another quality that distinguishes it sharply from gravitative matter. Neither is there any evidence that it is subject to friction, for bodies which have been moving in it for no one knows how long have not had their rates of motion changed by it. Comets have been known to move in the neighborhood of the sun with the velocity of nearly 400 miles per second, and not to suffer retardation, and light itself does not appear to be absorbed, in any degree, by traveling in it for any length of time. If it were, some stars would be coming into view in the direction in which the solar system is traveling, and others in the opposite direction would be dropping out of sight. Hence, we speak of it as being a *frictionless* medium.

Its qualities are alike in every direction; that is, it is *isotropic*.

It is all alike; there are no species of it; it is *homogeneous*.

It is capable of transmitting energy of certain forms with the velocity of light, and ability to do this is attributed to *elasticity*, though it is obvious that such elasticity as it has is wholly unlike the elasticity of any body of matter.

It is believed to be incapable of deformation; that is, its rigidity is incomparably greater than that of steel.

It is *incompressible*. Its *density* has been computed on the assumption that its ability to transmit energy is dependent upon the same physical conditions that enable matter to transmit it; but it is evident that the term is not to be understood to mean what we mean when we speak of the density of the earth or of the sun; for a body which is not capable of compression and is without molecular structure, can hardly be compared with one which is.

To describe the ether, there is evidently a necessity for appropriate terms, which, at present, we do not possess.

There is a certainty that it is capable of stress or pressure, for the phenomena of electricity and magnetism show this conclusively; and most astronomers, from Newton to those now living, have deemed it highly probable that the phenomena of gravitation are due to the action of this medium, rather than that one body can act upon another without it—that is, the ether pushes them towards each other—and attraction in the old sense has little to support it. Moreover, the velocity of gravitative action is believed to be not less than a million times that of light, and this shows that the character of the action that produces the gravitative pressure is totally different from that which sets up ordinary waves in the ether.

It appears, also, that the ether is a reservoir of energy of various kinds—energy which has been computed to be not less than 500 horse-power per cubic inch. It is capable of transforming energy—the energy of matter—and it holds what it gets until it can act upon some other mass of common matter; but it is capable of exchanging energy with matter. Thus, when a body like a weight is raised, work is done upon the ether, and exists as a stress in it. When the weight falls, the ether gives it back. When a hot body loses its heat by the process called radiation, the ether receives the energy as wave motion, and at once begins to distribute it. The energy is transformed from vibratory, in the molecules, to undulatory, in the ether, and, on meeting other molecules, is again transformed into heat. In like manner, with electric and magnetic actions, there is an exchange of energy from matter to ether, or *vice versa.*

Here are many ether phenomena, so utterly unlike the phenomena of ordinary matter that it is apparent the name matter ought not to be applied to it. Furthermore, it is also apparent that all attempts to describe the properties of the ether in the terms applicable to matter will be misleading. Here is a substance, which, experimentally, shows itself to be illimitable, continuous, homogeneous, isotropic, non-atomic, frictionless, incompressible, incapable of transforming its own energy, gravitationless, insensible to all nerves, compared with what is limited, discontinuous, heterogeneous, eolotropic, atomic, frictionable, compressible, capable of transforming energy, gravitative, and upon which all nerve action depends. Are not these distinctions wide enough to make one beware of thinking of them and describing their phenomena in the same terms?

[*To be concluded.*]

Stated Meeting, Tuesday, March 24, 1896.

MR. CLAYTON W. PIKE, President, in the chair.

INHERENT DEFECTS IN FUSE METALS EXPERIMENTALLY CONSIDERED.

BY WALTER E. HARRINGTON.

The development of the electrical arts, in the last few years, particularly in the direction of lighting and motive-power transmission, has been very great.

The fire risk, as well as the risk from failure of insulation and apparatus involved in electric work, is present in a greater or less degree, in accordance with the provision of the proper safeguards and selection of the best conditions. Notwithstanding the adoption of all provisions for protection and proper maintenance, safety devices are necessary, inasmuch as it is their purpose to provide for abnormal conditions, and to remove risks, which, although usually absent with perfect working and maintenance, may be brought into existence by accident or unforeseen defects. Such risks may be occasioned by outside interference with lines; or by lighting; by falling of poorly constructed signal and other wires upon overhead wires; by unusual wind or sleet storms; by failures of all kinds, as in the working of lamps, switches, etc. It is here that the safety device is found to be useful. Such devices are to the electrical system what check valves, overflow traps and safety valves are to steam and hydraulic systems. There is, of course, no room for doubt that if the insulation of all parts of the plant, as dynamos, lines, lamps, etc., were maintained always at its best, and if the mechanical strength of lines, hangers, poles, etc., could always be relied upon, and, further, if the effects of lightning induction were never present; there would be but little use for any purely electrical safety appliances, such as those for guarding against leaks and diversions of current. To expect such perfection of conditions is to expect too much. There will always remain opportunity for unskilled or careless handling so altering the conditions as to provoke troubles. There will always remain chances of undiscovered defects, chances of interference from outside. It is evident, therefore, that safety devices are and will continue to be important factors in electric work.

The last few months has witnessed a most remarkable awakening of interest in the question of the protection of electric circuits—an interest that is the more marked because of the entire lack of attention and misunderstanding formerly displayed. Engineers, boards of fire underwriters and municipal authorities, are realising that pronounced and heroic steps must be taken to prevent the recurrence of troubles occasioned by the present unreliable methods of protecting electric circuits. Mr. Wm. McDevitt, Chief Inspector of the Philadelphia Board of Fire Underwriters, one of the most conservative men in the profession, and possessed of ripe and broad experience in these matters, has recently put himself upon record in a paper, which, in its scope and bearing upon this vexed question of electric circuit protection, is entitled to be called authoritative. I refer to Mr. McDevitt's report to the Philadelphia Board of Fire Underwriters, entitled: "The Gross Untrustworthiness of Fuse Metals and Appliances as a Means of Protection for Electric Circuits."

The recent paper read by Professor Stine, of Armour Institute, Chicago, before the American Institute of Electrical Engineers, entitled "The Rating and Behavior of Fuse Metals," unqualifiedly condemns present methods and practices. The meeting last week of the various electrical interests, in New York, to discuss the rules of Boards of Fire Underwriters, discussed the question of the proper protection of electric circuits, in a manner which would lead a layman to think that the present methods of electric-circuit protection were wofully at fault.

A report of a committee of the German Union of Electricians, recently published, declares that no satisfactory results were reached concerning standards of lead-strip fuses, and offers a prize of $75 for the best solution of the problem. Up to this time no one has been able to claim the prize, and we feel sure that a standard can never be realised because of the inherent faults in fuse metals.

The theoretical considerations involved in fuse-metal practice are simple, and by reason of this simplicity the grave underlying *practical* faults are overshadowed and lost sight of by those who should lead and guide in the questions entering into the use of electric-circuit-protecting devices. That this element of theoretical simplicity has influenced the opinions of those of high scientific standing is very pertinently expressed by Prof. F. B. Crocker, in his discussion of Professor Stine's paper above mentioned. Professor Crocker says: "This paper, while dealing with a question that is by no means new, and should long ago have ceased to be a subject of discussion, is, nevertheless, one which is more constantly discussed and no more settled than many of the problems which are inherently far more difficult."

The physical conditions governing the fusion of a wire would appear to be very definite and easily determined; but the fact remains that to-day fuse wires are not to be relied upon, and the very term "fuse wire" is almost synonymous with unreliability.

Preece, of England, established the law that

$$C = ad^{\frac{3}{2}}$$

wherein

C = fusing current in ampères,

d = diameter of wire in inches,

a = constant depending upon the metal.

This law is concise, simple and readily understood. Constants (a) have been determined, and to all intents and purposes the whole subject of fuse metals is settled. It is here that practical knowledge of the actual conditions have been overlooked. Until recently the cry has been to adopt one particular fuse metal and certain specified sizes and dimensions of fuse blocks for different ampèrages, as it is claimed that standards such as this will overcome the objections heretofore raised, and that our troubles will be at an end.

It is here that the writer wishes to emphasise the fact—the practical fact—that fuse metals cannot be considered as the correct and safe means for protecting electric circuits.

Let us define what a fuse is. A fuse depends for its action upon the heating quality of the current. Time and current combined melt fuses. A fuse does not operate the instant that C becomes excessive, but does so when C^2t becomes excessive. (C stands for current in ampères, t for time in seconds.) A fuse is placed in a circuit as a protection against some unforeseen accidental condition. Unfortunately, an accident is an occurrence over which we have no control, and a short-circuit, or maximum abnormal condition, is as likely to arise as a mere overloaded condition. The facts are that, in practice, short-circuits, crosses and grounds occur almost exclusively, and the very condition under which fuses are designed and intended to act is not present, to wit: *time* and *current*. The current rises very high, far in excess of the rating and capacity of the fuse and of the circuit the fuse is to protect. It is the occurrence of the short-circuits which upsets the theories, as the fuse is intended to meet only a slightly overloaded condition of circuit.

In a screed recently published by a prominent fuse wire company, the requirement, as above outlined, of a long-continued, slightly overloaded condition of circuit (allowing sufficient time to elapse to heat the fuse metal to melting point) is very clearly expressed. Further, in order to emphasise the fact, the fuse wire company states expressly that, for any condition of circuit other than the above, a fuse is not adapted, and some other device, wherein magnetism is the medium to open the circuit, must be employed.

It is interesting to note the manner in which this popular misconception of the practical behavior of fuse metals has evidenced itself, and still more interesting is the fact that the very thing devised has not been adopted or applied in practice. I refer to magazine fuse blocks. There have been issued some twenty-seven patents upon forms of fuse blocks to renew fuses automatically. The reason magazine fuse blocks have not been adopted is due solely to the fact that, when circuits are opened by fuses "blowing" or "fusing," it is usually due to some short-circuited condition or other cause, such that attention is required upon the part of the operator, or person in charge, to seek for and remove the defect.

We will now consider in detail, and, by a few tests, demonstrate some of the inherent defects in fuse metals which condemn them as a safe and reliable means for protecting electric circuits from unusual and abnormal conditions.

First.—Fuses carry 50 to 200 per cent. current in excess of rated fusing current.

A 20-ampère fuse wire in a commercial fuse block permitted the passage of 50 ampères for five minutes. Upon the fuse "blowing," an arc was maintained until broken at switchboard by opening the circuit.

Second.—Under short-circuits, a fuse will carry excessively abnormal currents.

The following tests illustrate clearly how armatures in dynamos have developed in their insulation, owing to the mechanical stresses thrown upon the insulation upon the occurrence of short circuits. The arcing attendant upon a short-circuit does more damage for the time it acts than almost any other accompanying circumstance. The importance of opening the circuit in the shortest possible time after a fault occurs is apparent.

TESTS.

(1) Upon making a short circuit through a 5-ampère fuse wire, a magnetic circuit-breaker, in series with the fuse, was opened, although the circuit-breaker was adjusted to open upon 250 ampères.

(2) Similar test with a plug type of fuse of 10-light capacity opened the main magnetic circuit-breaker, set to open on 350 ampères.

(3) Similar test with a No. 30 B. & S. gauge copper wire opened the magnetic circuit-breaker set at 200 ampères.

(4) Grounding a gas-pipe and touching the gas-pipe with a wire connected to other side of the circuit, protected by a 20-ampère fuse, with a resistance in circuit such that not over 30 ampères could flow, caused a vicious arc, burning through the iron pipe, and ignited the gas. The same test performed with a magnetic circuit-breaker, in circuit set at 25 ampères, opened every time with no damage to pipe.

(5) A flexible cord was chafed and the wire strands were touching, causing a short-circuited condition, which is common in practice. Upon closing main switch, a short circuit occurred; resulting in firing or igniting the insulation, and the combustion of the cord.

Third.—Commercial fuse metals made of alloys, so as to have a low melting point, will "maintain" at a red heat.

The fire risk here is quite apparent, as the temperature is such that the metal is liable to ignite combustible material and set a building on fire.

Fourth.—The metals—copper, aluminum, iron, etc.—are not adapted for fuse metals, owing to the high temperatures required for fusing.

Melting points of metals are, in degrees F., as follows:

	Degrees F.
Antimony	880
Bismuth	512
Brass—cast	1,760
Copper	2,000
Iron	2,100
Lead	620
Tin	450
Zinc	780

By some the use of copper as a fuse metal has been unwisely urged. There is, of course, one very strong argument in its favor. For a given carrying capacity of copper, compared to metal such as lead and tin of a lower melting temperature, the cross section is much less, and, in the event of the fuse "blowing," there is, of course, much less metal to be disrupted and make current-carrying gases. However, the feature of "maintaining" at a red heat condemns high-melting point metals as fuse metals.

Owing to such metals being maintained at times at a temperature which causes oxidation and molecular changes, the life and characteristics of the metals are materially affected, thus introducing an additional uncertainty. Captain Brophy, Electrical Engineer with the State Commissioner of Wires of Massachusetts, has repeatedly stated, as the result of his experience of many years as an electrical inspector, that, "as fuse metals age, I find that their carrying capacity increases very rapidly."

Fifth.—Fuse metals cause arcing upon "blowing."

As stated before, if fuse metals would always blow under slight overload conditions for which they are designed, the time element of arcing upon "blowing" would not be much of an objection, though, of course, arcing with simple continued overload conditions does occur at times, and introduces a serious fire risk, as described by Mr. William McDevitt, in his paper above mentioned.

The real danger, however, consists in the arcing following the "blowing" of a large fuse in event of a short circuit. (Fortunately for the electrical profession at large, it very rarely occurs that the large-capacity fuses blow. Inquiries among engineers and contractors, as to whether they recall having large fuses blow, have invariably elicited a negative reply.) This is due, as is now understood, to the fact that C^2t is such a large quantity, and t is so short that C^2 on the smaller fuses or points of break burns itself out; or, as was recently the case in Philadelphia, upon the occurrence of a short-circuit, a fuse carried current without blowing, and wrecked the dynamos and engine.

In power transmission and central station work, when fuses have been known to blow under short-circuited conditions, much of the damage done the fuse terminals and surrounding insulation was due to the severe, vicious arcing, maintained, of course, at the expense of the terminals.

Sixth.—Enclosing a fuse is not safe, as the gases generated upon the fusion of the metal will continue to carry the current in the event of a short-circuit.

Arcing is a necessary evil; any effort to abolish it will be followed by disruptive E.M.F.'s and breaking down of insulation. Since arcing is present, let us reduce its destructive effects to a minimum. An arc is a flexible floating conductor; enclosing it in anywise makes it more dense, and its carrying capacity is thus materially increased. Practical test has demonstrated conclusively the importance of using as short a fuse as possible, in order to reduce to a minimum the formation of gas—the longer the fuse, the more metal to fuse and form gas. Further, the terminals should be so protected as to reduce to a minimum the formation of gas and arcing after the circuit is free from the first disruptive induced electromotive forces present upon the first opening of the circuit. Let the fuse blow or vent in a fuse chamber; prepare the chamber, if you choose, so that the flame cannot get out to ignite any combustible, but provide plenty of vent for the gases.

Seventh.—Fuse metals are very sluggish in fusing.

This is a proposition which the previous tests demonstrate. The evil effects of this quality are obvious. It has been urged by those not familiar with the practical operation of magnetic circuit-breakers that they have a "hair-trigger action," and that this militates against their practical utility, owing to their tendency to open at the slightest provocation. This argument is not based upon facts, as in practice magnetic circuit-breakers are adjusted to open upon a current some 25 per cent. in excess of the maximum normal rises in current.

It is apparent, from the above tests and conclusions, that fuse metals are not a satisfactory means for protecting electric currents. The other factors of uncertainty, such as shape, position, length, temperature, alloy, Peltier effect, expansion and contraction, terminals, effect of current flow, etc., have not been considered, as they are now pretty well understood.

If simple slightly overloaded conditions are all that fuses are to guard against, then fuse metals properly made and rated are probably a better protection than none at all; but, under actual conditions in practice, for circuits over 10 ampères capacity, it is very poor engineering practice to use fuse metals.

It might be interesting to know that some electrical engineers of the highest standing have abandoned the use of fuse metals on circuits of large capacity.

After an arraignment, showing the absolute worthlessness of a device so long established as the fuse, it is pertinent here to refer to the device which is supplanting it. I refer to the magnetic circuit-breaker, an apparatus that automatically opens an electric circuit through the medium of the magnetic quality of the current. Since the magnetic action of the current is simultaneous with the flow of current, the time of opening is dependent, then, upon the mechanical means set into operation by the magnetic action of the current flow.

The method usually employed to effect this opening is as follows: An armature of an electro-magnet moves upon the flow of a predetermined current, tripping a catch which permits a spring to throw out a switch. The features in this construction alone are faulty, owing to the constant time required to open the circuit, which, in the event of a short-circuit, allows the current to assume enormous proportions. The proper construction of a magnetic circuit-breaker should be such that, as the conditions in the circuit to be protected become more and more severe, the device shall automatically open more and more quickly. This feature of an inverse time element is incorporated in the devices before you, the action of which is as follows: The plunger moves up and trips a catch, and continues upward and imparts its acquired energy to aid in wiping or throwing out the switch arm. Under severe overload conditions, a point or flow of current can be reached when the velocity of the plunger with its acquired energy is greater than the compressed spring, resulting in the opening of the switch in a manner independently of the spring.

The following test was made to illustrate this construction: A 12-ampère I-T-E magnetic circuit breaker was taken, and the spring used to aid in throwing out the switch was removed. Upon closing the circuit the plunger moved up with such a velocity that the switch was thrown out by the impact. This feature is certainly very interesting, as it exemplifies in practice the conditions established by Helmholtz' law for sudden changes in the condition of a circuit, to wit:

$$C = \frac{E}{R} \left(1 - e^{-\frac{Rt}{L}}\right)$$

C = Current in ampères.
E = Applied electromotive force.
R = Ohmic resistance of circuit.
E = Naperian base of logarithms.
L = Coefficient of self-induction in henrys.
t = Time of opening circuit in seconds.

This law shows mathematically that the more quickly a circuit can be opened the less will be the resulting flow of current. Further, the quicker the switch leaves its contacts, the less the arcing effect, as the current is given less time to heat up the final leaving points.

The following are the salient features entering into the correct design of magnetic circuit-breakers:

(1) The magnetic circuit-breaker must have the feature of opening the circuit in progressively less time as the conditions of the protected circuit approach a short-circuit; that is, it must have an inverse time element. The electro-magnetic part of circuit-breakers must be designed to develop more energy than is necessary to trip the retaining catch. The additional energy developed must be applied directly to aid in opening the switch.

(2) A magnetic circuit-breaker must have no springs in its adjustment.

(3) Insulation must not enter into the construction of the trigger or catch.

(4) All bearing pins and parts liable to be affected by corrosion or rust must be of phosphor-bronze, and moving iron parts must be copper-plated.

(5) The armature, or plunger, of the magnetic circuit breaker must not act on the retaining catch or switch arm unless a free preliminary movement precedes such action.

NOTES AND COMMENTS.*

ACETYLENE AND INSURANCE.

At a recent meeting of the Philadelphia Fire Underwriters' Association, Mr. Chas. A. Hexamer gave his views on acetylene gas, viewed from the insurance standpoint:

"Acetylene gas burns with an exceedingly luminous flame of much greater candle-power than the best city gas. If furnished to the consumer through underground pipes in a manner similar to the present system of city gas supply, there would be no greater risk from its use than from the use of city gas. In order to cheapen its use, however, it is proposed to supply acetylene gas to the consumer in cylinders, in a liquefied state, under a pressure variously estimated at 750 to 1,000 pounds. It is stated that a cylinder of gas, 4 inches in diameter, 4 feet high, will contain enough gas in a liquefied state to supply an ordinary ten-room dwelling with gas for three months. These cylinders it is proposed to connect directly with the gas pipe in a building; when empty, to be disconnected and a new cylinder substituted. It is necessary to reduce the 1,000 pounds pressure in the cylinder to a small fraction of a pound at the burners. This is done by a Pintsch valve, a rather complicated mechanism.

"Two important questions present themselves at this point:

"(1) What would be the result if a possible fire in the building should reach the acetylene cylinder?

"(2) What would be the result if the reducing valve failed and the entire gas pressure in the cylinder were suddenly thrown into the gas pipes in the building?

"It is stated that, while it is true that an increase of temperature involving the gas cylinder would produce increased pressure, before the pressure would cause a rupture of the cylinder (which is said to be tested to 3,000 pounds) decomposition of the acetylene gas into carbon and hydrogen would result, with no explosive effect. This result, it is claimed, has been obtained by heating a small cylinder of liquefied gas in a fire to a cherry-red heat. While this may be true (and similar decomposition of gases—notably hydrogen sulphide, which in a cylinder subjected to heat deposits free sulphur and liberates hydrogen—are known), it remains to be demonstrated whether cylinders of liquefied acetylene gas can safely be heated without disastrous results, the fact being that the quantity of hydrogen liberated equals in volume the acetylene decomposed; the danger of a rupture of the cylinder, therefore, is not eliminated by the decomposition of the acetylene. The result of failure of the reducing valve, which operates automatically, can be easily imagined. The liberating of a gas at nearly 1,000 pounds pressure into gas pipes not intended to carry more than a few pounds pressure must necessarily produce disastrous results.

---

* From the Secretary's monthly reports.

"From the above it will be seen that the points of interest to the underwriter are the presence of cylinders of liquefied gas in buildings in case of fire, and possible failure of the valve intended to reduce and regulate the slight pressure of gas necessary at the burner. There is no reason why the objection from these points should not be overcome. Cylinders of compressed gas can and should be located outside the building, and a safety valve can be provided to empty the cylinder, discharging the gas into the open air outside of the building, in case the reducing value fails to act.

"Besides furnishing acetylene in liquefied state under pressure, it is proposed to introduce small gas machines intended to generate acetylene directly from the calcium carbide. Apparently no special hazard attaches to this plan, provided the gas machine be located outside the building, and provided the calcium carbide be stored in a dry place and free from an accidental contact with water, which, generating the gas, might cause a fire or an explosion by coming in contact with an open light.

"It is too early to formulate rules and requirements for safe introduction of acetylene gas for illuminating purposes. The subject has hardly passed the experimental stage. The result of an accident to a cylinder of the compressed gas brought it forcibly to the attention of the underwriter. That the disaster was the result of the accidental and possibly careless breaking of a valve being experimented with cannot be allowed to modify the deduction to be drawn. As an illuminant, acetylene is so far superior to ordinary city gas that, if the claim made as to the relative cheapness of its production can be substantiated, its general introduction may be expected. A careful consideration of the subject by underwriters' associations is necessary. In the meantime, underwriters are wise who carefully consider each application for the use of this new gas in its present state of development, and, until proper regulations and requirements have been formulated for its safe introduction, refuse to grant permission for its use in buildings covered by their policies."

MECHANICAL FLIGHT SUCCESSFULLY ACCOMPLISHED BY PROFESSOR LANGLEY.

It has been an open secret that the eminent physicist who occupies the post of Resident Secretary to the Smithsonian Institution, has, for a number of years, been quietly prosecuting investigations into the problem of artificial flight, and, from time to time, the newspaper press has contained notices of his progress towards its solution. The latest publication on this subject contains the highly interesting announcement of the successful flight of a model machine constructed on his plans.

While no details are given of the construction and operative mechanism, the facts of this remarkable performance, vouched for, as they are, by so competent an eye-witness as Professor Bell, are important enough to place on record, if, indeed, they do not mark the beginning of a new epoch in the history of mechanical flight.

Prof. Alexander Bell, who was associated with Professor Langley in the test recently made public, describes the successful experiments, which were carried out near Occoquan, Va., on May 6th, as follows:

"Last Wednesday, May 6th, I witnessed a very remarkable experiment with Professor Langley's aerodrome on the Potomac River. Indeed, it seemed to me that the experiment was of such historical importance that it should be made public.

"I should not feel at liberty to give an account of all the details, but the main facts I have Professor Langley's consent for giving you, and they are as follows:

"The aerodrome, or 'flying machine,' in question was of steel, driven by a steam engine. It resembled an enormous bird, soaring in the air with extreme regularity in large curves, sweeping steadily upward in a spiral path, the spirals with a diameter of perhaps 100 yards, until it reached a height of about 100 feet in the air, at the end of a course of about a half mile, when the steam gave out and the propellers which had moved it stopped.

"Then, to my further surprise, the whole, instead of tumbling down, settled as slowly and gracefully as it is possible for any bird to do, touched the water without any damage and was immediately picked out and ready to be tried again.

"A second trial was like the first, except that the machine went in a different direction, moving in one continuous gentle ascent as it swung around in circles like a great soaring bird. At one time it seemed to be in danger, as its course carried it over a neighboring wooded promontory, but apprehension was immediately allayed as it passed 25 or 30 feet above the tops of the highest trees there, and, ascending still further, its steam finally gave out again, and it settled into the waters of the river, not quite a quarter of a mile from the point at which it arose.

"No one could have witnessed these experiments without being convinced that the practicability of mechanical flight had been demonstrated.

"ALEXANDER GRAHAM BELL."

Professor Langley supplements the foregoing by the following statement, giving some important data regarding the recent experiments:

"The aerodrome, or flying machine, has no gas to lift it, as in the case of a balloon, but, on the contrary, is about 1,000 times heavier, bulk for bulk, than the air on which it is made to run, and which sustains it somewhat in the way in which thin ice supports a swift skater.

"The power is derived from a steam engine through the means of propellers, but owing to the scale on which the actual aerodrome is built, there has been no condensing apparatus to use the water over and over. Enough can be carried for only a very brief flight, a difficulty which does not belong to larger machines than the present example, in which the supporting surfaces are but about 14 feet from tip to tip.

"The distance flown each time was about one-half mile. The rate of speed depends (as in the case of any vehicle on land) on whether it is going on a level or uphill. In the case of this last trial of May 6th, the machine was ascending, that is to say, it was going uphill all the time, and went through a distance of one-half mile or more in one and one-half minutes, or at the rate of a little more than twenty miles an hour."

CALCIUM CARBIDE AND ACETYLENE.

The following abstract of the report of Messrs. Houston, Kennelly and Kinnicutt, the experts commissioned by tne *Progressive Age* to investigate and report on the Willson process, as operated at Spray, N. C., is quoted from the *Electrical World:*

The report of Houston, Kennelly and Kinnicutt was made to settle the question of cost of the material. They visited the works of the Willson Aluminum Company, at Spray, N. C., and made an examination and test of the process of manufacture of calcium carbide, as it is there carried on. The report is given in all its details, only a few of which can be given here. A description of the plant is given; it includes two alternators of 120 kilowatts, operating at a voltage of 1,155, the currents being transformed down to about 100 volts for furnaces. In the very carefully made tests two complete runs were made in the same furnace on two different days; in the first one, 1,200 pounds of lime and 800 pounds of coke were placed in the mixer, and thence in the furnace for three hours; the mean primary current was 156 ampères at 1,000 volts; the charge which was taken out consisted of 226·5 pounds of gross calcium carbide and 1,332 pounds of mixture unacted upon; the second run was somewhat shorter, namely, two hours and forty minutes, and contained about the same charge, the resulting material being 203 pounds gross calcium carbide; the mean power was 205·6 horse-power at the transformers, and 195·3 at the furnace; the average yield of the net calcium carbide was 5·09 cubic feet of acetylene per pound. A detailed table of the yield of calcium carbide in these test runs is given; in this it is stated that the pounds of gross carbide per furnace horse-power hour averaged 0·3905, and the net carbide 0·3723. The methods and results of the chemical analysis are given. This is followed by a detailed estimate of the cost, the concluding figures of which are as follows: Cost of plant, $11,955; labor, $11; materials, $14.39; these, together with power ($3.37), interest, depreciation, etc., amounted to $32.767; this is based on an output of gross carbide of 2,000 pounds per twenty-four hours; the freight charges on lime and coke are very heavy at Spray, and add materially to the cost. The net carbide gave an average yield of 4·926 cubic feet of acetylene gas per pound; pure calcium carbide should yield theoretically about 6, so that the net carbide averaged 82·1 per cent. of the theoretical yield. This report is followed by a supplementary one by Messrs. Houston and Kennelly, in which they give an estimate of the cost of manufacture on a more extended scale, and at a locality where the materials would be less expensive; they assume a plant having an output of 5 short tons of the gross material per day, and operating 300 days a year by water-power, which latter costs $5 per horse-power per year; the investment will be $44,700, the labor $7,550; insurance, taxes, interest, depreciation, oil, etc., $5,575; water-power and rent, at the rate of 1,200 horse-power, $6,000; materials, $10,937, making a total of $30,062 per year for 2,500 short tons of gross carbide, which amounts to $20·040 as the cost for 1 short ton. General equations are deduced for calculating the cost under different conditions; in a perfect furnace and if the line costs $2.50 per short ton, coke $2 75 and an electrical horse-power $12 at the furnace, the limiting cost of the carbide would be $8,734 per short ton; owing to the impurities of the materials, and as the furnace is not theoretically perfect, the minimum value would be $14.97; under favorable conditions, which can be realised in peculiar localities, the total cost per short ton in a plant producing 5 tons a day might be $20.

TESLA'S NEW LIGHT.

The *Public Ledger*, of May 21st, contains the following interesting item of news:

It is announced that Nikola Tesla has solved the problem which he set before himself many years ago, and which may revolutionise the system of electric lighting. It is, electrical experts say, the nearest perfect adaptation of the great force of nature to the use of man.

In Mr. Tesla's laboratory in Houston Street, is a bulb not more than 3 inches in length, which, when the current is turned into it, becomes a bulb of light. The mat is almost imperceptible. With it a very large room is so lighted that it is possible to read in any corner. Yet this is done without the attachments necessary in existing lights.

The rays are so strong that the sharpest photographs may be taken by them. No new dynamo is required to produce the current. There is no danger of harmful shock in its use.

Stories have come from time to time from Mr. Tesla's laboratory that he was experimenting on a light of this sort. Rumors of success and failure have followed each other, and Mr. Tesla's friends were inclined to doubt that he would succeed. A half-dozen times the discovery was at his finger tips, only to elude him. But now he has told his friends of his success.

Mr. Tesla has been working for many years on his theory of the necessity and practicability of the conversion of electricity. The present incandescent light gives only 3 per cent. of illuminating power; the other 97 per cent. is wasted in heat.

In accordance with his theories, which have been already applied successfully to the economical transmission of the electric fluid, he applied himself to the saving of some of this wasted energy in electric light.

The bulb which he has perfected gives 10 per cent. of light and loses 90 per cent. of energy. Mr. Tesla declares that he will, with the aid of a few more experiments, be able to produce 40 per cent. of light, so that the waste will be reduced to only 60 per cent., or 37 per cent. less than at present.

The principle of the light is vibration. The illumination is secured by means of what Mr. Tesla terms a vibrator within a bulb, which holds the vibrating needle within a vacuum. The needle vibrates so rapidly that the figures per second sound imaginary, but it is this intensity of energy which gives the light its brilliancy and its apparent steadiness. The lights do not have to be renewed.

REMOVING RESTRICTIONS FROM THE FRENCH UNIVERSITIES.

It will be of interest to American students desiring to avail themselves of the advantages of the French higher schools, to learn that the Conseil Supérieur de l'Instruction Publique, of France, has issued a decree which removes the restrictions imposed on American and other foreign students in French universities and gives them a status similar to that accorded them by the German universities. The memorial addressed to the Conseil by Prof. H. J. Furber, of the University of Chicago, called attention to the fact that there were only 30 students at the Sorbonne, while there were 200 at the University of Berlin. The conditions will now probably be substantially changed by the new decree.

Franklin Institute.

[*Proceedings of the stated meeting, held Wednesday, May 20, 1896.*]

HALL OF THE FRANKLIN INSTITUTE,
PHILADELPHIA, May 20, 1896.

JOS. M. WILSON, President, in the chair.

Present, 208 members and visitors.

Additions to membership since last report, 5.

The Secretary presented and read a communication from Mr. A. v. Kerpely, the President of the Executive Committee of the Mining and Geological Millenial Congress, to be held in Buda-Pesth, September 25–26, 1896, in connection with the commemoration of the Millenial Anniversary of the foundation of the Hungarian kingdom.

The President was authorised, by vote, to use his discretion in naming a delegate to represent the Institute at this Congress.

Mr. Richard W. Barkley, of New York, gave an account of the process of Professor Joly, of Dublin, of reproducing the colors of nature by photography, and showed a number of lantern slides illustrating the process. The meeting passed a vote of thanks to Mr. Barkley for his interesting communication.

Mr. Arthur Kitson presented an illustrated paper on the Kitson gas producer.

Prof. Arthur W. Goodspeed, University of Pennsylvania, by special invitation, exhibited a number of lantern slides of Röntgen radiographs, made by himself, which illustrated in a remarkable manner the great advances that had been made in this newly-opened field of investigation, since its first announcement, about six months ago.

The speaker was accorded the thanks of the meeting.

The Secretary exhibited and commented on some new cellulose products made by Messrs. Cross, Bevan and Beadle, of London, and the product known as steel wool, of which specimens were shown.

On motion of Mr. G. M. Eldridge, the following preamble and resolutions were adopted without dissent, viz.:

WHEREAS, The Act of Congress of the United States in force prior to January, 1895, provided for the distribution of the monthly volumes of patents to such libraries as would pay for the binding thereof and comply with certain regulations relating thereto ; and

WHEREAS, The Franklin Institute of the State of Pennsylvania, for the Promotion of the Mechanic Arts, has and various other public libraries have complied with said regulations and paid for binding, and have received and have now on their shelves all such monthly volumes up to and including the month of December, 1893, to the great accommodation and advantage of the public seeking information regarding patents ; and

WHEREAS, On the 12th of January, 1895, an Act of Congress was passed inhibiting such distribution of these volumes, whereby great inconvenience has resulted to such seekers for information ; and

WHEREAS, The presence and use of these monthly volumes of patents is of great service to the general public, but of no profit or advantage to the Franklin Institute or to such other libraries or to its or their members, beyond other persons ;

Be it resolved, By the Franklin Institute of the State of Pennsylvania, for the Promotion of the Mechanic Arts, that the Congress of the United States be and hereby is respectfully petitioned to take such action as will restore the privileges of distribution of such monthly volumes of patents to the condition in which it existed prior to the passage of the Act of January 12, 1895;

And be it further resolved, That the Congress of the United States be and hereby is respectfully petitioned to take such action as will class the bound monthly volumes of patents with other publications of the United States, so that they may be distributed, like such other publications, to libraries which are designated as depositories of public documents, as heretofore and now provided by law in relation to such other publications.

Adjourned.

WM. H. WAHL, *Secretary.*

T
1
F8
v.141
~~Physical &~~
~~Applied Sci.~~
~~Serials~~

Engineering

Franklin Institute,
Philadelphia
Journal

PLEASE DO NOT REMOVE
CARDS OR SLIPS FROM THIS POCKET

UNIVERSITY OF TORONTO LIBRARY

ENGIN STORAGE